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CENTRAL VALLEY WATER RESOURCE STUDY

Federal Water Pollution Control Administration
San Francisco, California

March 1970

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CENTRAL VALLEY WATER RESOURCE STUDY

BY

U. S. DEPARTMENT OF THE INTERIOR

Federal Water Pollution Control Administration
Pacific Southwest Region, San Francisco, California

U. S. Bureau of Reclamation
Region 2, Sacramento, California

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I. INTRODUCTION

This report is in response to the request of the Director of the Bureau of the Budget expressed in his memorandum of April 7, 1968, to the Secretary of the Interior for a Central Valley Program Special Study, described as follows:

> "Recent studies on water quality problems suggest that current project analysis is failing to take into account all of the social costs which result from water resource development in the Central Valley of California. Furthermore, individual project analyses do not adequately take account of interaction among projects which affect the overall costs and benefits of future water systems development. The study should analyze the Central Valley program as a total water system rather than as a collection of projects which are separately analyzed."

PURPOSE

The

There is growing concern over water quality in the Central Valley of California, particularly in the Sacramento-San Joaquin Delta. Federal actions on both water quality standards and water project development are of major significance in future water management policy. The purpose of this study is to provide a better basis to make decisions with respect to Federal water development and water quality control plans, projects, and programs in the Central Valley in the immediate and short-term future, 1970-80.

The study reflects projected changes in water development and use and the impact on water supplies and water quality from future agricultural, municipal, industrial, economic, and social growth in the Central Valley. Study emphasis centers on the impacts of the Federal development program. Developments in the state, local, or private sectors generally are not dependent upon Federal decisions; however, they are included, scheduled, and considered in evaluation of Federal water development programs.

STUDY PLAN

A Departmental task force was established and an Outline of Plan of Study prepared (Appendix 1). The actual study was conducted in the California field offices of the Federal Water Pollution Control Administration[1/] and the Bureau of Reclamation.

[1/] The Federal Water Quality Administration since April 3, 1970.

II. SUMMARY AND CONCLUSIONS

This joint study by the Bureau of Reclamation and the Federal Water Pollution Control Administration was undertaken in response to a request from the Bureau of the Budget with the understanding that it was to be a limited-scope, exploratory effort, based on existing data and analysis. The study was expected to produce either answers to the specific study-purpose questions or, if that proved impossible given the study design constraints, an indication of why the questions could not be answered.

The study has concluded that detailed questions about Federal-State-local program interrelationships, alternative programs and policies for water development and quality control, comprehensive benefit and cost analysis of alternative policies and programs, appraisals of water quality effects of each proposed project, and monetary impact of alternative water quality standards and alternative water pricing policies are most difficult, and sometimes impossible, to answer based upon information presently available. More study would provide some answers but even a very great effort would not answer other questions, due to the nature of the situation and the problems.

The Central Valley is expected to experience a continued increase in development, assuming adequate amounts of high quality water are available. By 2020 population is projected to increase three- to five-fold, irrigated acres by 50 percent or about 3 million acres, and net water use by over 50 percent. Both projected importation of water from the North Coast to the Central Valley and exportation to Southern California will increase dramatically. By 1970 almost 23 million acre-feet will be developed for use within the Central Valley, export, and environmental control within the Delta. Over 3 billion dollars of Federal and State construction funds will be needed between 1970 and 1990 to meet the water needs of the year 2020; about half is for conveyance facilities.

Existing Federal water resource projects provided about 25 percent of the surface supply derived from Central Valley streams in 1960, and Federally developed supplies are expected to provide almost 40 percent by 2000. Existing Federal projects have been important in preserving water-use benefits threatened or decreased by non-Federal water resource developments. However, this preservation has not been universal in its effectiveness and beneficial uses have been adversely influenced, some seriously.

Adverse influences on some of the beneficial uses of Central Valley streams are not of recent origin. Although large-scale Federal and State involvement in irrigation supply is relatively recent, private and local district works have been extensive for many years. As early as 1873, irrigation diverters along the San Joaquin River reduced its flow in one reach to zero or near zero during the irrigation season. Beneficial uses have been adversely influenced here and elsewhere by withdrawal of water for consumptive purposes and because associated waste waters and return flows have caused a quality deterioration of the water remaining in the stream. Three major quality problems are worthy of emphasis.

1) The general deterioration of lower San Joaquin River water quality might be exemplified by frequent failure in recent years to meet the recently adopted State-Federal water quality standards at Vernalis. During summer and fall, flow consists largely of irrigation return flow. As the San Joaquin enters the Delta, its water quality problems are compounded by additions of municipal and industrial wastes and reduced assimilative capacity caused by channel dredging.

2) Tulare Basin ground-water quality is deteriorating because of a long term unfavorable salt balance condition arising from lack of drainage to the ocean. Although this situation is largely caused by "natural" materials, increasing consumptive use of water has accelerated the deterioration process. As a result, ground water has been abandoned for some uses in parts of the basin.

3) The capacity of San Francisco Bay and the Delta to assimilate municipal, industrial and agricultural wastes from the surrounding area is rapidly being approached and significant water quality deterioration has occurred. Improvement of degree of municipal and industrial treatment with continued local disposal into these confined waters appears to offer only interim improvement in water quality. Transport of nonreclaimable wastes to the ocean is advocated as the long-term solution.

The history of the Central Valley, especially the San Joaquin and Tulare Basins, argues that additional development will occur even in the absence of additional imported water supplies by more extensive exploitation of the ground water. Such additional development together with that part of present development supported by ground-water overdraft would flourish only until increasing pump lifts and surface and ground-water quality deterioration forced its abandonment. Prior to such an occurrence, however, the magnitude of the potential economic loss, local political pressure and other considerations would likely stimulate construction of a rescue project--whether by local, State or Federal interests it is impossible to say. The amount of required imported water would be higher than presently contemplated if irreversible damage to the ground-water basin occurred.

An alternate course of action, and one considered in some detail in this report, is the timely implementation of a comprehensive, regional water resource management system including both water supply and waste management aspects. Analysis of available information has permitted tentative identification of certain major elements of this system; local, State and Federal interests are all significantly involved:

1) The water quality management aspects of reservoir and conveyance systems must be considered fully in design and operation to minimize adverse effects on the fishery, general ecology of the stream and adjacent lands, water quality, and recreational use of the streams involved. Opportunities for environmental enhancement can frequently be identified and implemented.

2) The increase in municipal and industrial waste loads in the Central Valley will necessitate a several-fold increase in treatment capacity and a large expenditure for facility construction. Possible cost through 2020 for the Central Valley outside the Delta-Sacramento-Stockton area is 200-500 million dollars for treatment and waste transport facilities. Even this expenditure for treatment will not eliminate the need for flow maintenance in the stream system. Water reclamation is potentially very significant in augmenting the present water supply.

3) Municipal and industrial sewerage in the San Francisco Bay and Delta would be accomplished by a combined wastewater reclamation-marine disposal system if the recommendations of the State San Francisco Bay-Delta program are followed. The cumulative cost estimated for this favored option may total 4.3 billion dollars by 2020 (1969 dollars). The formation of a regional agency, either single or multipurpose, was recommended to plan, design, construct and operate a comprehensive water pollution and water quality control system throughout the twelve counties comprising the Bay-Delta area. Advanced waste treatment with local disposal/reclamation has been advocated for municipal and industrial wastes from the Sacramento and Stockton metropolitan areas.

4) Drainage facilities to maintain the productivity of the San Joaquin Valley and especially the land-locked Tulare Basin are required in addition to the San Luis Drain. The need for drainage facilities is recognized and indeed the Secretary of Interior has indicated that resolution of the drainage problem will be necessary before the East Side Project can proceed. A capital investment of 200-500 million dollars is estimated for handling this drainage problem.

5) The San Joaquin River system is no longer capable of assimilating and transporting additional residual wastes free of economic and social costs. The construction of waste treatment facilities, a Master Drain, and water development projects as considered herein including fishery releases from the East Side Canal to various tributaries of the San Joaquin River appears to form the basis of an acceptable management system. Some seasonal adjustment of flow would be necessary in average years, and additional releases would be required in dry years. Although the Delta-Mendota Canal cannot provide relief to the tributaries, it and the California Aqueduct should be used to preserve water quality in the lower San Joaquin River, both as an interim measure and in conjunction with the East Side Canal as parts of the long-term solution.

6) Water quality control by freshwater flow maintenance is postulated as the most feasible means of controlling mineralization of Delta waters resulting from both seawater incursion and transport of salts by inflowing streams and waste discharges, and as a means to supplement other actions to insure compliance with other criteria in the water quality standards. Flows and water quality are presently adequate and future action is largely directed toward preservation of quality to support present and future beneficial uses. The Peripheral Canal would have the capability to effectively manage localized water quality problems in the Delta.

A more dominant role for future Federal water resource development is envisioned, especially in protecting beneficial uses which are widespread or national in scope. Since water resource development objectives are rapidly changing, there is constant scrutiny of existing and proposed projects, and appropriate modifications are made. The Central Valley Project including the proposed East Side Canal and Peripheral Canal will be operated to meet water quality standards for total dissolved solids and chloride concentrations in the Sacramento-San Joaquin Delta as approved by the Secretary of Interior to protect fishery, recreational, irrigation, municipal and industrial uses.

The study finds that a large investment in water quality management systems must accompany economic development if environmental quality is to be preserved and that such an investment can likely be supported by an economic test.

III. PRESENT CONDITIONS

Appreciation of the present state of water development in the Central Valley of California, either if one views the actual scene or sees it reflected in the mirror of statistics, requires some understanding of the conditions which governed developments in the past. These conditions were not the same as those which govern in the present. Nor is it reasonable to expect that present conditions will prevail for long periods in the future.

Few of the works which supply today's water were built with today's technology, today's labor conditions, today's method of financing, or today's legal and managerial institutions. The results of 120 years of water development - some five generations - is like an old family homestead, enlarged and altered as the family grows but always adapted to its basic function. Thus, relatively primitive and highly sophisticated systems exist side by side, each built to the standards existing at its time of construction and each continuing to serve an essential purpose.

CENTRAL VALLEY BASIN DESCRIPTION

The Central Valley Basin is comprised of two major river basins, that of the Sacramento River on the north and the San Joaquin River on the south. The combined basin extends nearly 500 miles in a northwest-southeast direction and averages about 120 miles in width. It includes more than one-third of California. The basin is entirely surrounded by mountains except for a narrow gap on its western edge through which the combined Sacramento and San Joaquin Rivers flow to the Pacific Ocean through San Francisco Bay. The valley floor is a gently sloping, practically unbroken alluvial plain which comprises nearly one-third of the basin area. It is about 400 miles long and averages about 45 miles in width. The surrounding two-thirds of the basin is mountainous. To the east of the main valley is the massive Sierra Nevada which rises gradually from the edge of the valley floor to the rugged peaks of the divide, several of which are more than 14,000 feet in elevation. The coast ranges, to the west of the main valley, are less rugged and lower in altitude, their crests being generally less than 4,000 feet in elevation except at the northern end. The coast ranges separate the interior Central Valley from the Pacific Ocean.

Population, agriculture, and industry are principally on the main valley floor. The surrounding mountains play an important part in this valley development, however, because the heavier precipitation in the mountains provides the main source of the water supply essential for the successful development of the valley. The mountain regions, in addition, have considerable areas of land suitable for crop production and grazing purposes, and are rich in minerals, forests, hydroelectric power sites, and recreational areas. It has been found desirable, however, for convenience of study and discussion, to divide the basin into four major hydrologic areas which are described in the following paragraphs. (See figure 1.)

Sacramento Basin

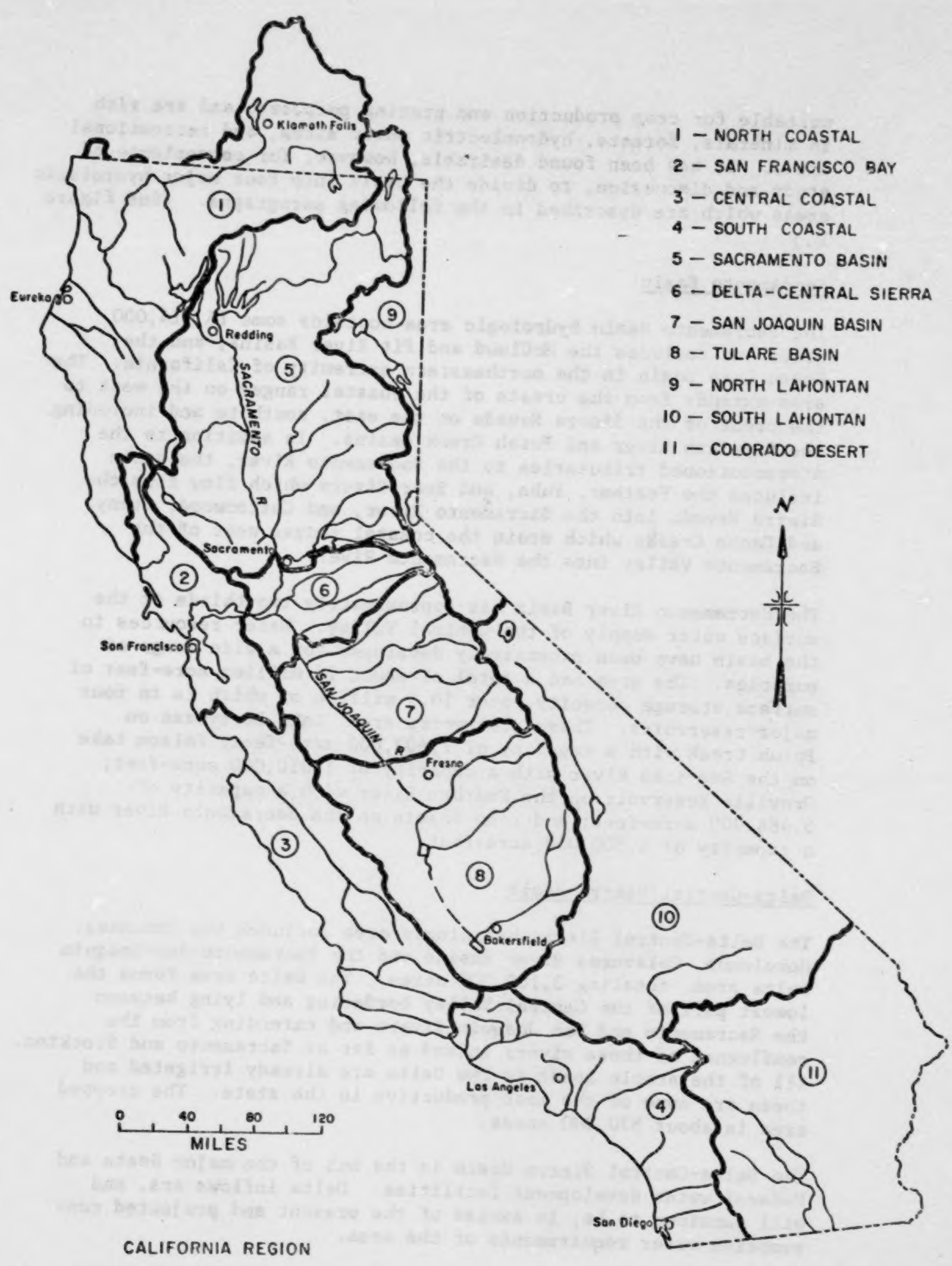
The Sacramento Basin hydrologic area contains some 16,714,000 acres and includes the McCloud and Pit River Basins, and the Goose Lake Basin in the northeastern extremity of California. The area extends from the crests of the coastal ranges on the west to the crest of the Sierra Nevada on the east, south to and including the American River and Putah Creek Basins. In addition to the aforementioned tributaries to the Sacramento River, the basin includes the Feather, Yuba, and Bear Rivers which flow from the Sierra Nevada into the Sacramento River, and Cottonwood, Stony and Cache Creeks which drain the coastal ranges west of the Sacramento Valley into the Sacramento River.

The Sacramento River Basin has approximately two-thirds of the surface water supply of the Central Valley. Water resources in the basin have been extensively developed for a wide range of purposes. The area has a total of about 16 million acre-feet of surface storage capacity, over 10.5 million of which is in four major reservoirs. These reservoirs are: Lake Berryessa on Putah Creek with a capacity of 1,602,000 acre-feet; Folsom Lake on the American River with a capacity of 1,010,000 acre-feet; Oroville Reservoir on the Feather River with a capacity of 3,484,000 acre-feet; and Lake Shasta on the Sacramento River with a capacity of 4,500,000 acre-feet.

Delta-Central Sierra Basin

The Delta-Central Sierra hydrologic area includes the Cosumnes, Mokelumne, Calaveras River Basins and the Sacramento-San Joaquin Delta area, totaling 3,109,000 acres. The Delta area forms the lowest part of the Central Valley bordering and lying between the Sacramento and San Joaquin Rivers and extending from the confluence of these rivers inland as far as Sacramento and Stockton. All of the arable lands in the Delta are already irrigated and these are some of the most productive in the state. The cropped area is about 570,000 acres.

The Delta-Central Sierra Basin is the hub of the major State and Federal water development facilities. Delta inflows are, and will continue to be, in excess of the present and projected consumptive water requirements of the area.


O Klamath Falls
1 — NORTH COASTAL
2 — SAN FRANCISCO BAY
3 — CENTRAL COASTAL
4 — SOUTH COASTAL
5 — SACRAMENTO BASIN
6 — DELTA-CENTRAL SIERRA
7 — SAN JOAQUIN BASIN
8 — TULARE BASIN
9 — NORTH LAHONTAN
10 — SOUTH LAHONTAN
11 — COLORADO DESERT
Eureka
Redding
SACRAMENTO R
Sacramento
San Francisco
SAN JOAQUIN R
Fresno
Bakersfield
Los Angeles
San Diego
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0 40 80 120
MILES

CALIFORNIA REGION

STREAMS AND CALIFORNIA SUBREGIONS

Figure 1

San Joaquin Basin

The San Joaquin Basin hydrologic area extends from the vicinity of Fresno northward to the Sacramento-San Joaquin Delta subregion and encompasses 7,017,000 acres. Principal tributaries to the San Joaquin River on the east side of the basin include the Stanislaus, Tuolumne, Merced, Chowchilla, and Fresno Rivers. On the west side of the basin, streams include Hospital, Del Puerto, Orestimba, San Luis, and Los Banos Creeks.

The area is a rich agricultural region. Surface water serves about two-thirds of the subregion and ground water the remaining third. The basin as a whole has an abundant supply of water; however, there are local areas where ground-water levels are declining.

Tulare Basin

The Tulare Basin hydrologic area which has a land area of 11,076,000 acres includes all Central Valley stream basins between Fresno and Bakersfield that drain into Tulare Lake rather than northward into San Joaquin River. A portion of the floodflow of Kings River is tributary to San Joaquin River by way of Fresno Slough, and prior to irrigation development Tulare Lake also overflowed into San Joaquin River during periods of extreme flood. The Kings River, which carries eroded material from the Sierra Nevada, has built up a low, broad ridge across the trough of the valley so that the Tulare Basin has essentially no surface water outlet. Principal streams flowing into Tulare Basin in addition to Kings River include Kaweah, Tule, and Kern Rivers which drain from the Sierra Nevada. No large streams enter the basin from the coastal ranges and the Tehachapi Mountains.

The Tulare Basin is one of the richest agricultural regions in the United States. The highly developed agricultural economy of the basin is dependent upon runoff from the Sierra Nevada, imports from basins to the north, and ground water to supply its water needs.

San Francisco Bay Basin

The San Francisco Bay hydrologic area as indicated on figure 1, contains some 3,650,000 acres and includes the Russian River Basin and several smaller basins tributary to the Pacific Ocean as well as the San Francisco Bay system itself. The San Francisco Bay system, which is of primary interest in the current study, is composed of Suisun, San Pablo and San Francisco Bays. This series of bays provides the outlet to the ocean for all Central Valley flows reaching the Delta. Nearly all the displacement flow through the bays is supplied from this source.

LAND USE AND ECONOMIC DEVELOPMENT

Agriculture in the Central Valley Basin developed through three overlapping stages--the cattle ranching of the early days, followed by dry farming of small grains, and finally the specialized and intensified irrigation farming of today.

Cattle raising was the primary agricultural activity for the decade following the discovery of gold, but at the same time other forms of agriculture were being established, including grain farming.

The dominant position of stock raising was brought to a sudden end by the disastrous drought of 1863-64 which resulted in the loss of practically all of the cattle in California. This factor plus the growth of population, the increased demand for grain, and the development of the railroads following 1869, stimulated grain production. Dry farming of wheat and barley continued to expand until the latter part of the century, then declined as other grain regions were developed.

As the population increased and the settlers became aware of the great value of a water supply during the growing season, the third phase or era, that of irrigated agriculture with more intensive land use, began. At the present time, the livestock ranching of the first phase continues in the peripheral areas or in conjunction with other stages, and the grain farming of the second stage continues around the edge of the valley.

Meanwhile, intensive irrigation farming began the expansion which has continued to give it its present dominant position.

The principal manufacturing activity is food processing which includes the packaging of food for consumer use, canning of fruits and vegetables, and the production of frozen and concentrated foods.

Mining, lumbering, and other manufacturing contribute to the economy.

The Central Valley Basin contains 38,341,000 acres of land. About 65 percent is privately owned, and the remainder Federally owned, state or other public lands. The land ownership status as of 1965 (table 1) indicates approximately 32 percent of the basin is Federally owned, including nearly 23 percent administered by the Forest Service.

Agricultural Development

Under present conditions of development in the Central Valley Basin, almost 6 million acres are irrigated annually or approximately 70 percent of the land irrigated throughout California.

Table 2 shows the gross irrigable land, the irrigated area, and the crops grown on the irrigated land for each of the hydrologic areas of the basin. Of the 5,985,000 acres of land irrigated in 1960, some 2,710,000 acres, or over 45 percent, are in the Tulare Basin. Irrigated lands used for pasture amounted to 1,110,000 acres in 1960.

California's agricultural production includes more than 275 farm products - crops and livestock - some 80 being raised on a large scale. The irrigated crops produced in the Central Valley are illustrative of this extreme diversification of agriculture. A substantial acreage of rice, which is grown in water, is produced in the trough of the Sacramento Valley, while Acala cotton has become a dominant crop in the San Joaquin Valley. Irrigated orchards and vineyards are found throughout the entire area. Citrus fruits are produced in an extensive orchard belt on the east side of the Tulare Lake Basin and to a small extent in Glenn and Butte Counties in the northern portion of the Sacramento Valley. San Joaquin County is the leading producer of asparagus which is grown on the muck and peat soils of the Delta.

According to the 1964 Census of Agriculture, the value of farm products in the 31-county Central Valley Basin was almost 2 billion dollars. The entire state in 1963 produced over 35 million tons of crops with crops valued at over 2 billion dollars and livestock and poultry another 1½ billion dollars. California is the leading state in crop value and ranks second to Iowa in livestock production.

Although extensive areas are devoted to so-called truck or cash crops, a substantial portion of the irrigated land in the Central Valley is used for production of forage. Livestock raising continues to be one of the important agricultural pursuits of the area. In terms of cash value, in 1963 the four most important crops were cattle and calves, dairy products, cotton, and hay.

The San Joaquin Valley is California's leading farm area in value of farm products and value of farms. Table 3 summarizes information on the makeup, size, products, and value of the Central Valley farm areas. The San Joaquin Valley, which includes Tulare Lake Basin, leads other areas of the state in number of acres harvested, variety of crops produced, and total number of farms. Three of the San Joaquin Valley counties--Fresno, Tulare, and Kern--are the leading counties in the nation in value of farm products sold.

Table 1. Central Valley Land Ownership Status

		Acres (1,000)
Federal lands		
Department of Agriculture		
Forest Service		8,651
Department of Interior		
Bureau of Land Management		1,665
Fish and Wildlife Service		50
National Park Service		1,728
Bureau of Reclamation		148
	Subtotal	3,591
Department of Defense		
Corps of Engineers (Civil)		58
Other agencies		114
	Subtotal	172
Other		8
Total Federal lands		12,422
State owned lands		352
Other public lands		478
Privately owned lands		
Individual or corporate		25,018
Indian trust lands		71
	Subtotal	25,089
Total land in Basin		38,341

Table 2. Total irrigable acres and irrigated land acres, by crops (1960)

	Sacramento Basin	Delta-Central Sierra Basin	San Joaquin Basin	Tulare Basin	Total Central Valley
Gross irrigable land (1,000 acres)	4,000	1,600	2,840	5,030	13,470
Irrigated (1,000 net acres)	1,400	715	1,160	2,710	5,985
Crops on irrigated acres (1,000)					
Grain and hay	15	35	45	675	770
Rice	275	10	25	15	325
Cotton	-	-	90	625	715
Sugar beets	55	50	15	20	140
Miscellaneous field	150	100	120	265	635
Alfalfa	150	75	200	410	835
Pasture	455	170	330	155	1,110
Truck	75	180	135	110	500
Deciduous fruit and nuts	225	55	130	105	515
Subtropical	-	-	-	60	60
Vineyard	-	40	70	270	380
TOTAL	1,400	715	1,160	2,710	5,985

In 1967, over 1,640,000 acres were irrigated with a water supply from the Central Valley Project. Crops produced from these lands were valued at $593,800,000. Thus, the crop value per irrigated acre averaged of over $360.

Nonagricultural Development

Food processing is the principal manufacturing activity in the Central Valley. One of the primary enterprises of this group is the canning of fruits and vegetables. This industry had its origin in 1859, when some 5,000 cases were handpacked, but it was not until the invention of the tin can about 1885 that the business developed on a major scale. Since that time expansion has been rapid. Packaging of food and production of frozen and concentrated foods for consumer use have been greatly expanded. In 1963, the State processed some 2½ billion dollars worth of food products.

The metropolitan areas of Bakersfield, Fresno, Sacramento, and Stockton in 1963 had 1,694 manufacturing establishments employing some 69,332 people. The value added by manufacture was $1,013,458,000 with over $532,304,000 in Sacramento alone.

Primarily owing to its magnificent harbor, the San Francisco Bay area has long been the principal trading center of the Pacific Coast. Major primary and secondary manufacturing industries were early attracted to this area, and it soon became the banking and financial capital of the west. The manufacturing complex has grown greatly over the years. Civilian employment in 1965 totaled 1,621,900 with 370,000 employed in manufacturing. Total manufacture of the San Francisco - Oakland area for 1963 amounted to nearly 2.6 billion dollars. Agriculture has been primarily oriented to the local market with the exception of the varietal wine grape industry and the fruit and nut orchards.

Production of minerals in California totaled $1,699,359,000 in 1966. The principal mineral products are petroleum, natural gas, cement, and stone, but there is a widely varied list of other minerals produced in smaller quantities. Petroleum production in three leading counties of the Central Valley, Fresno, Kern, and Kings Counties, in 1966 amounted to 143,887 thousand barrels, valued at $328,654,000. Natural gas produced in principal Central Valley counties in 1966 amounted to almost 465 billion cubic feet, valued at $145,422,000.

Agricultural development has created a large demand for fertilizer and agricultural chemicals. Fertilizer consumption in California was 327,000 tons in 1942, and by 1965 had increased to 3,135,910 tons. The Central Valley accounts for a major portion of this use.

Table 3. Makeup, size, and products of Central Valley farm areas

	Unit	Sacramento Valley[a]	San Joaquin Valley[a]	Central Valley
Land area	1,000 acres	6,758	18,456	25,214
Area in farms	1,000 acres	5,063	11,788	16,851
Total cropland	1,000 acres	2,547	5,585	8,132
Value, farmland & buildings	1,000 dollars	1,292,688	3,646,222	4,938,910
Value, all farm products sold in 1959	1,000 dollars	303,696	1,176,409	1,480,105
Number of farms		12,192	34,890	47,082
Average per farm:				
Total	acres	415	346	358
Cropland	acres	209	160	173
Value, land and buildings	dollars	106,028	104,506	104,900
Value, farm products sold	dollars	24,909	33,718	31,437
Number of farms classified by major source of income:				
Fruit and nut farms		2,437	10,644	13,081
Vegetable farms		239	848	1,087
All other field crop farms		1,701	5,847	7,548
Dairy farms		1,155	3,991	5,146
Poultry farms		441	1,502	1,943
Livestock farms		1,407	2,240	3,647
General farms		658	1,872	2,530
Miscellaneous unclassified		4,235	7,837	12,072
TOTAL CLASSIFIED FARMS		12,273	34,781	47,054

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[a] Parsons, Philip S. and McCorkle, C.O., Jr., 1963, A Statistical Picture of California's Agriculture: University of California Circular 459.

The State ranks second in the nation in volume of timber cut, second in lumber produced, and third in plywood manufacturing. In 1963, over 5 billion board feet of lumber were produced in California, and after manufacture it had a value of $511,509,000. In 1965, the Central Valley produced 36 percent of the logs and 20 percent of the value added by manufacture of lumber, wood, paper and allied products in the State. The forests of the Central Valley Basin comprise most of the pine region of California and 42 percent of the commercial forest.

WATER RESOURCES DEVELOPMENT

Water Supply

The water supply of the Central Valley is chiefly derived from runoff of the mountains and foothills of the Sierra Nevada, with minor amounts from coast range streams entering the west side of the valley. Rainfall contributions on the floor of the basin add to the supply. About four-fifths of the annual precipitation occurs during the winter between the last of October and first of April, but snow storage in the high Sierra delays the runoff from that area until April, May, and June, in which months half the normal annual runoff occurs. By July the flow of all streams drops to a small fraction of the average discharge.

The annual runoff into the valley since 1904 has varied from an estimated maximum of more than 60 million acre-feet in 1906-07, to a recorded minimum of less than 8,500,000 in 1924. A 40-year average of 33 million acre-feet has been estimated for the period 1903-04 to 1942-43. An average of 18 million acre-feet was recorded for the 7-year period of critically low runoff which occurred between October 1927, and September 1934. Rainfall records which began in 1849 at Sacramento indicate that 7-year period to have been the driest in the 95 years of record. The average natural annual runoff of each of the major streams entering the Central Valley and the combined runoff of minor streams is shown in table 4 for the critical 7-year period and also for the 40-year period.

A complex aquifer system underlies the Central Valley. Approximately 5,000 square miles in the western central part of the San Joaquin Basin is under artesian pressure; elsewhere ground water is often semiconfined. The maximum depth to water is more than 900 feet; however, ground water may occur near ground surface. Total storage capacity in a depth zone of 200 feet below ground surface is 93 million acre-feet in the San Joaquin Basin and 33 million in the Sacramento Basin. Low yield in some areas is considered a limiting factor in utilization of the water. Ground-water temperatures average about 65° but range from about 45° to 105° F. The dissolved-solids content of the water averages about

Table 4. Natural runoff of Central Valley streams

Stream	Location of gaging station	Average annual runoff	
		7-year average 1927-28 to 1933-34 inclusive (1,000 acre-feet)	40-year average 1903-04 to 1942-43 inclusive (1,000 acre-feet)
Sacramento River	Red Bluff	4,950	8,350
Feather River	Oroville	2,600	4,450
Yuba River	Smartsville	1,400	2,350
Bear River	Van Trent	160	320
Cache Creek	Capay	150	460
Putah Creek	Winters	170	430
Stony Creek	Orland	170	390
Deer Creek	Vina	135	210
Mill Creek	Los Molinos	135	200
Thomes Creek	Paskenta	110	190
American River	Fair Oaks	1,550	2,750
Mokelumne River	Clements	440	770
Cosumnes River	Michigan Bar	170	370
Calaveras River	Jenny Lind	70	200
San Joaquin River	Friant	1,060	1,820
Tuolumne River	La Grange	1,150	1,900
Stanislaus River	Knights Ferry	680	1,200
Merced River	Merced Falls	570	1,020
Fresno River	Adobe Ranch	45	120
Chowchilla River	Buchanan Damsite	35	100
Kings River	Piedra	1,010	1,720
Kern River	Bakersfield	370	760
Kaweah River	Three Rivers	240	420
Tule River	Success Damsite	55	140
Other streams	Edge of Valley	975	2,360
Central Valley Basin Total		18,400	33,000

500 p.p.m. but ranges from 64 to 10,700 p.p.m. The predominant water type varies with location in the aquifer but calcium, magnesium, sodium, bicarbonates, sulfate, and chloride are all present in significant quantities.

Water Use

The primary use of water in the Central Valley is for the production of agricultural crops. However, water is also utilized by urban communities, industrial plants, and for other purposes. In 1960, the total water use was estimated to be 22 million acre-feet. Approximately 12 million acre-feet of this water was drived from surface supplies.

These surface supplies have been developed by local irrigation districts, municipal utility districts, county agencies, private companies or corporations, and state and Federal agencies. Of the 12 million acre-feet of surface water use, the 1960 use of Federally developed water amounted to approximately 3 million acre-feet. In 1960, the California State Department of Water Resources was not delivering any large quantities of water in the Central Valley. Approximately 75 percent of the surface water being used was developed by local entities for local in-basin use.

In the mountains and foothills a large amount of hydroelectric power is generated at locations that combine appreciable heads with adequate water supplies. The streams and lakes constitute outstanding natural resources for recreational development and for propagation of fish life.

Navigation on the Sacramento River forms an important part of the transportation facilities of the valley. River barges move forest products and agricultural produce from the valley and import such items as gasoline, oil, and manufactured merchandise.

Flow of fresh water through the Sacramento-San Joaquin Delta transports residual wastes from the Central Valley and controls the degree of salt water incursion from the San Francisco Bay System.

There is a demand for adequate sustained flows in the principal streams entering San Francisco Bay to permit the propagation of fish both for recreational and commercial salmon catches. The spawning and growth of the young of several important species take place in the Central Valley. Fish hatcheries have been provided in some instances to replace upstream spawning areas to which access is no longer possible.

Surface Water Development

Extensive use of the water resources of the Central Valley began in the years following the gold rush of 1849, when thousands of miles of ditches were constructed in the Sierra Nevada for placer, quartz, and hydraulic mining. Water still serves the mining industry but use for that purpose is now overshadowed by the major irrigation, municipal and hydroelectric power uses of more recent times.

Extensive irrigation works have been constructed in the Central Valley. In 1960 these works delivered irrigation water to almost 6 million acres of land, or more than one-sixth of all the irrigated land in the United States. Thousands of miles of canals and laterals have been constructed to distribute water by pumping or gravity diversion from the main streams of the valley. To secure an adequate water supply throughout the entire irrigation season, hundreds of reservoirs, both large and small, have been constructed for water storage. The investment in reservoirs with capacities in excess of 10,000 acre-feet amounts to $1,300,000,000.

Municipal water supply systems have been constructed for all the important cities and towns in the Central Valley. The most notable municipal developments, however, are those of the East Bay Municipal Utility District (Oakland and adjacent cities) and the city of San Francisco, both of which obtain the major portion of their water from reservoirs in the Sierra Nevada.

Water resources in the mountainous areas of the Central Valley Basin have been developed extensively for production of hydroelectric power. At present there are 114 hydroelectric plants in the basin with a total installed capacity of 7,870 megawatts, which is more than 20 percent of the total hydroelectric capacity of the United States.

Table 5 gives physical and cost data on surface water resource developments in the Central Valley Basin. The total investment for existing facilities and associated water conveyance facilities amounts to 3.4 billion dollars. The 102 major reservoirs in the Central Valley in 1969 had a gross storage capacity of over 25 million acre-feet. Of this, 10.5 million were in Federal projects, 12.3 million in non-Federal, and 2.2 million in the joint Federal-State San Luis Project.

Ground-Water Development

Present irrigation, municipal, and industrial works include thousands of wells which tap underground reservoirs containing large, though not unlimited, supplies of water.

Table 5. Major water resource development projects existing or under construction

	Sacramento Basin	Delta-Central Sierra Basin	San Joaquin Basin	Tulare Basin	Central Valley
Reservoirs					
Number	56	8	32	6	102
Capacity (1,000 acre-feet)					
Gross	15,920	1,240	5,850	2,050	25,060
Active	12,920	1,200	5,460	2,000	21,580
Flood control reservation	260	420	1,030	1,060	2,770
Conveyance facilities					
Number	29	8	23	3	63
Length (miles)	420	190	910	360	1,880
Power and pumping plants	68 & 0	5 & 3	28 & 3	13 & 4	114 & 10
Installed capacity (MW)	4,250	570	1,470	1,580	7,870
Average annual energy (million KWH)					
Generated	17,600	1,000	7,200	1,500	27,300
Required	0	2,100	700	9,200	12,000
Capital cost ($1,000,000)	1,620	360	720	700	3,400

The San Joaquin Valley has the largest ground water pumpage of any valley in the United States and the largest overdraft. Widespread pumping began about 1900 and has increased at an accelerated rate since 1940. The water deficiency in the San Joaquin Valley which existed as early as 1921 was one of the major incentives for undertaking studies that developed into the Central Valley Project and the State Water Plan.

Estimates indicate that ground water is presently utilized for irrigation from more than 50,000 wells in the San Joaquin Valley, representing a 1¼ billion dollar capital investment.

In 1952, ground-water pumpage in the San Joaquin Valley was on the order of 7,500,000 acre-feet per year. The 1968 pumpage was estimated at about 11,500,000 acre-feet.

The pumping draft in the Sacramento Valley in 1950 was in the order of 1,300,000 acre-feet. The 1968 pumpage was estimated at about 3 million acre-feet.

Ground-water overdraft caused by pumping for agricultural use has occurred in numerous areas throughout the Central Valley. Development and importation of supplemental supplies has alleviated the overdraft in certain instances. Additional works are under construction or planned by Federal and State agencies to eliminate most of the remaining overdrafts, but control and management of ground-water pumping also will be necessary.

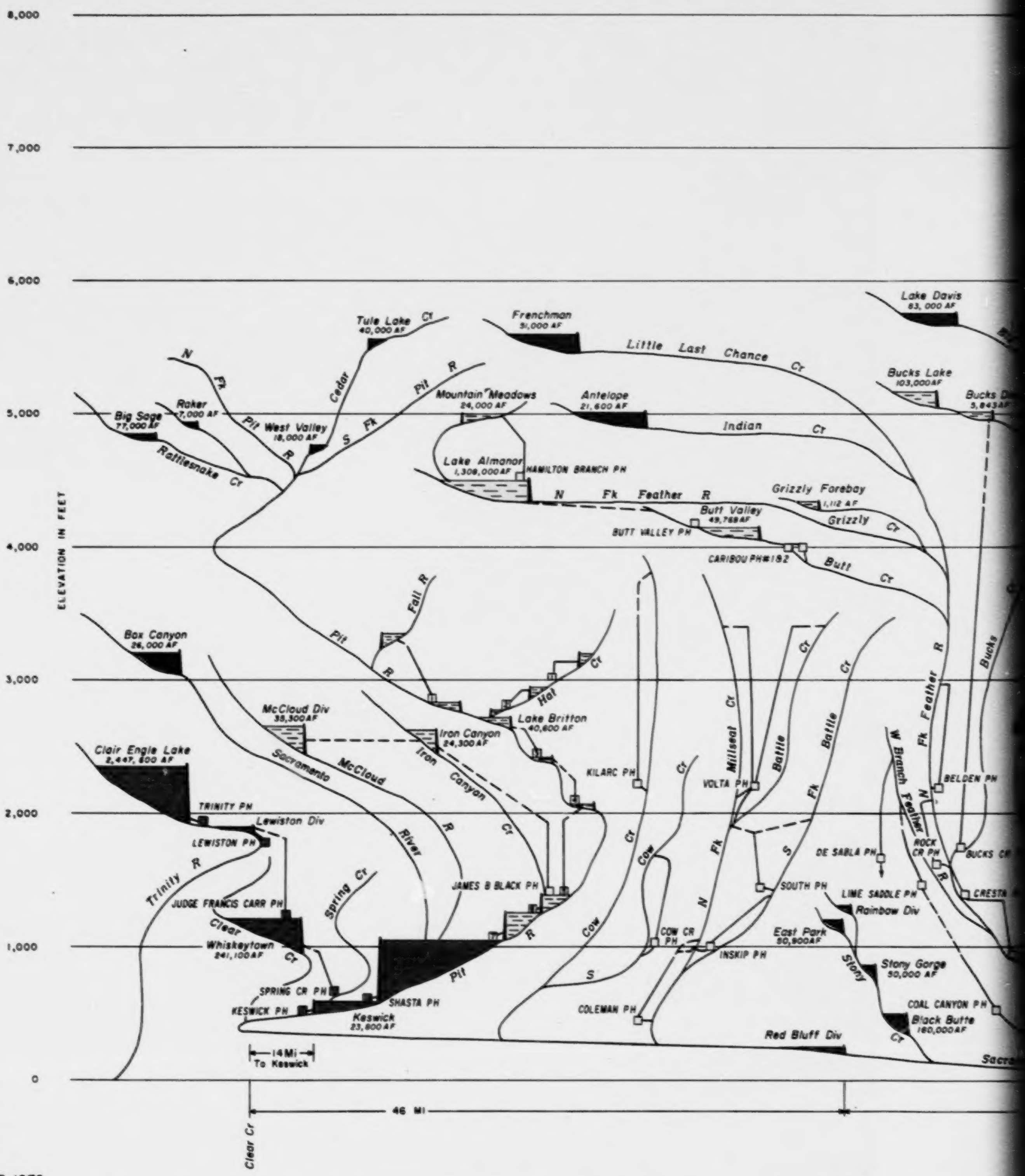
INVENTORY OF PROJECTS

The principal reservoirs and powerplants in the Central Valley Basin, including facilities under construction, are shown on figure 2. This schematic profile illustrates the extent and complexity of the water development in the basin, both in terms of water operations and in the variety of operating entities.

An inventory of local, State, and Federal surface water developments in California, including cost and additional physical data, is given in State of California, Department of Water Resources, Bulletin No. 160-66 "Implementation of the California Water Plan," Appendix F, dated August 1967.

WATER QUALITY AND HEALTH FACTORS

Water quality throughout the Central Valley is presently adequate to sustain beneficial uses, with certain exceptions. Quality problems are almost absent in the mountainous areas and indeed this has been a significant factor leading to development of municipal supplies at the higher elevations. On the valley floor,


8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
ELEVATION IN FEET
Lake Davis
83,000 AF
Frenchman
51,000 AF
Little Last Chance Cr
Tule Lake
40,000 AF
Cr
Cedar
N Fk Pit R
Pit R
Bucks Lake
103,000AF
Bucks D
5,843AF
Mountain Meadows
24,000 AF
Antelope
21,600 AF
Indian Cr
Big Sage
77,000 AF
Raker
7,000 AF
West Valley
18,000 AF
S Fk
Rattlesnake Cr
Lake Almanor
1,308,000AF
HAMILTON BRANCH PH
N Fk Feather R
Grizzly Forebay
1,112 AF
Butt Valley
49,769AF
Grizzly Cr
BUTT VALLEY PH
CARIBOU PH#1&2
Butt Cr
Fall R
Pit R
Box Canyon
26,000 AF
Hat Cr
Lake Britton
40,600 AF
McCloud Div
35,300AF
Iron Canyon
24,300AF
Clair Engle Lake
2,447,800 AF
Sacramento River
McCloud R
Iron Canyon Cr
KILARC PH
Cr
Cr
Millseat Cr
VOLTA PH
Battle Cr
Battle Cr
Feather R
Bucks
W Branch Feather
N Fk
BELDEN PH
TRINITY PH
Lewiston Div
LEWISTON PH
Trinity R
Cow Cr
Cow
S Fk
N Fk
DE SABLA PH
ROCK CR PH
BUCKS CR
R
SOUTH PH
LIME SADDLE PH
CRESTA
Rainbow Div
JAMES B BLACK PH
JUDGE FRANCIS CARR PH
Spring Cr
Clear Cr
Whiskeytown
241,100AF
R
Cow
COW CR PH
INSKIP PH
East Park
50,900AF
Stony Cr
Stony Gorge
50,000 AF
SPRING CR PH
S
Pit
SHASTA PH
KESWICK PH
Keswick
23,800 AF
COLEMAN PH
COAL CANYON PH
Black Butte
160,000AF
Red Bluff Div
Sacra
14Mi
To Keswick
46 MI
Clear Cr

A

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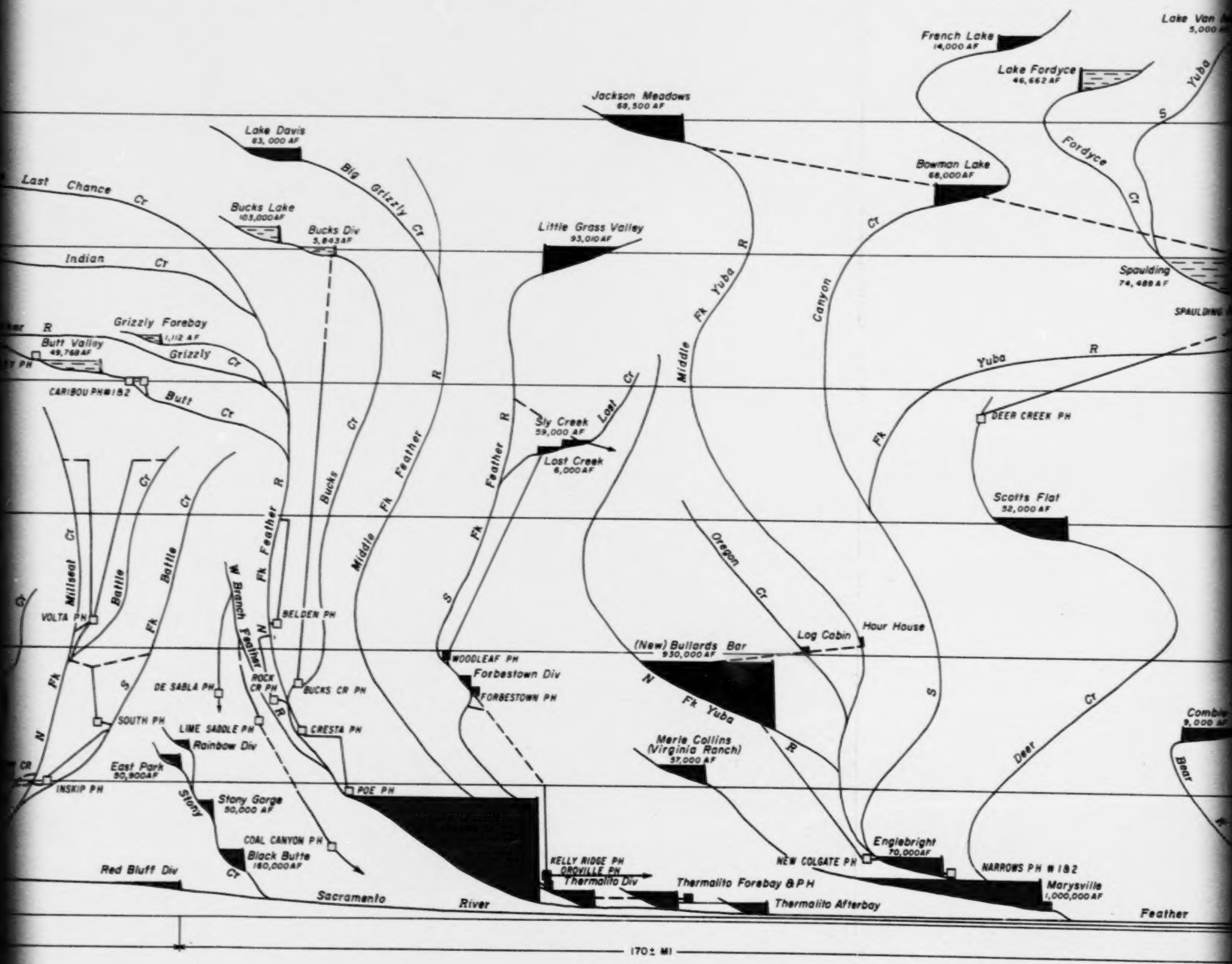
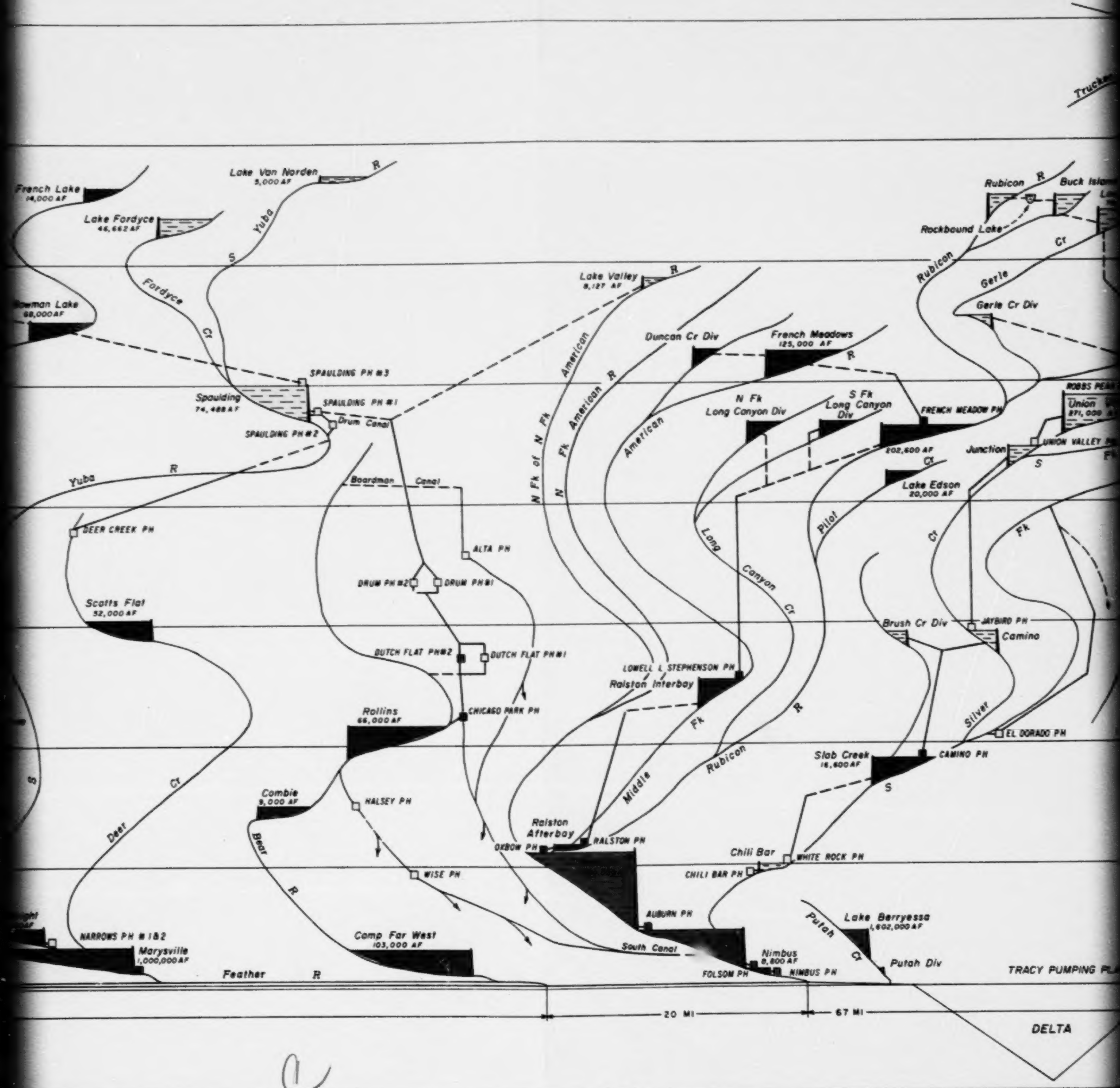
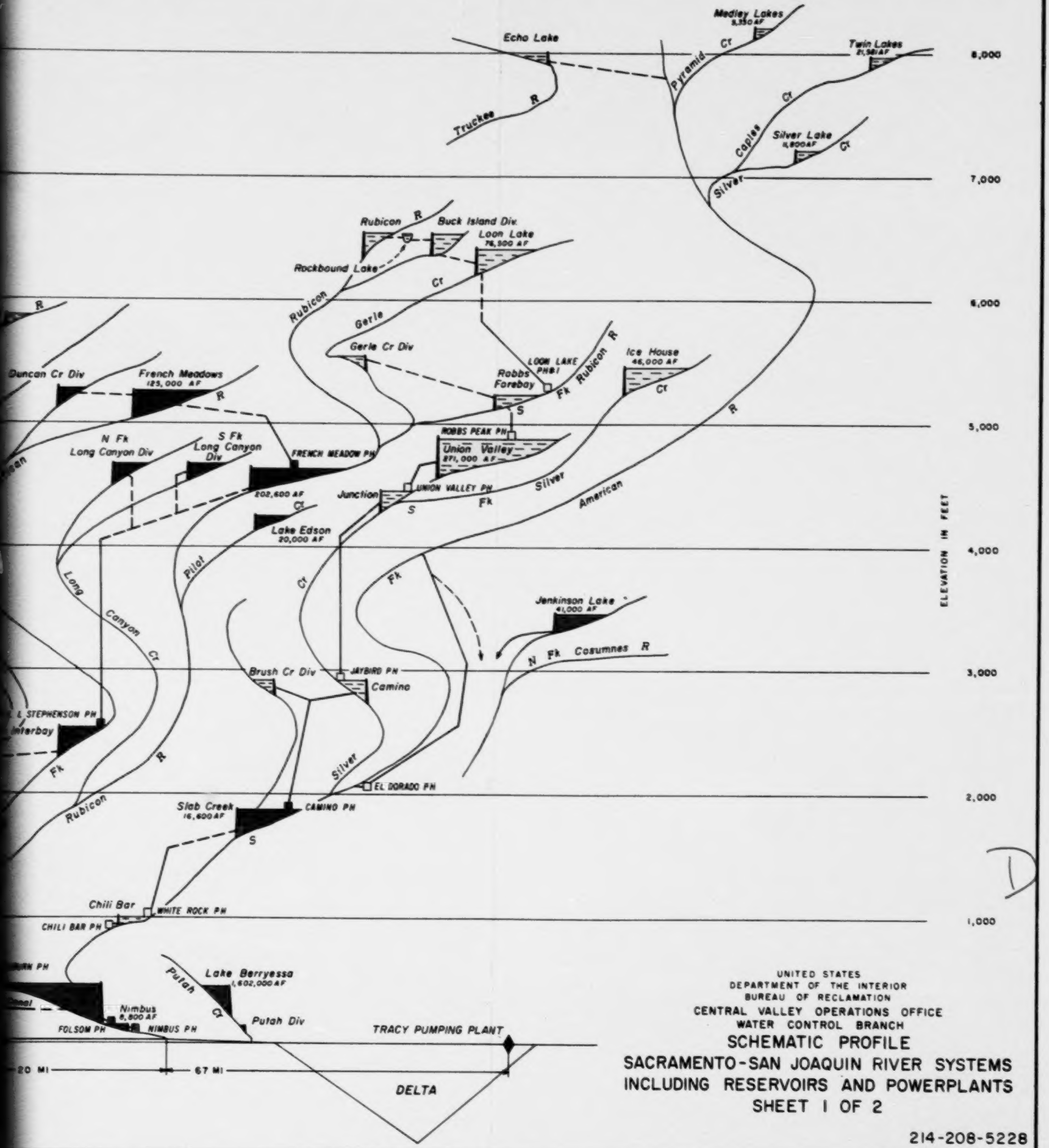
■ Corps of Engineers
■ California Department of Water Resources
■ Water Districts, Authorities, Municipalities, & Individuals
□ Power Companies & Municipal Utility Districts


French Lake
14,000 AF
Lake Van N
5,000 A
Lake Fordyce
46,662 AF
Yuba
S
Jackson Meadows
68,500 AF
Fordyce
Cr
Lake Davis
83,000 AF
Bowman Lake
68,000 AF
Last Chance Cr
Big Grizzly Cr
Bucks Lake
103,000 AF
Bucks Div
5,843 AF
Little Grass Valley
93,010 AF
Canyon Cr
Spaulding
74,488 AF
Indian Cr
Middle Fk Yuba R
SPAULDING
Grizzly Forebay
1,112 AF
R
Butt Valley
49,768 AF
Grizzly Cr
PH
CARIBOU PH # 1 & 2
Butt Cr
Yuba R
Lost Cr
Sly Creek
59,000 AF
Lost Creek
6,000 AF
DEER CREEK PH
S Fk Feather R
Fk Feather R
Middle Fk Feather R
Bucks Cr
Millseat Cr
Battle Cr
Battle Cr
Fk
Scotts Flat
32,000 AF
Oregon Cr
Cr
W Branch Feather
N
VOLTA PH
BELDEN PH
Log Cabin
Hour House
(New) Bullards Bar
930,000 AF
WOODLEAF PH
Forbestown Div
FORBESTOWN PH
S
N Fk
DE SABLA PH
ROCK CR PH
BUCKS CR PH
R
N Fk Yuba R
S
SOUTH PH
LIME SADDLE PH
CRESTA PH
Rainbow Div
Merle Collins
(Virginia Ranch)
57,000 AF
Deer Cr
Combie
9,000 AF
Bear
CR
East Park
50,900 AF
INSKIP PH
POE PH
Stony
Stony Gorge
50,000 AF
COAL CANYON PH
Black Butte
160,000 AF
Cr
Englebright
70,000 AF
NEW COLGATE PH
KELLY RIDGE PH
OROVILLE PH
NARROWS PH # 1 & 2
Red Bluff Div
Thermalito Div
Thermalito Forebay & PH
Marysville
1,000,000 AF
Sacramento
River
Thermalito Afterbay
Feather
170± MI

15


Truckee
French Lake
14,000 AF
Lake Van Norden
5,000 AF
R
Lake Fordyce
46,662 AF
Yuba
S
Fordyce
Cr
Bowman Lake
68,000 AF
SPAULDING PH #3
Spaulding
74,488 AF
SPAULDING PH #1
Drum Canal
SPAULDING PH #2
Yuba
R
Boardman Canal
DEER CREEK PH
ALTA PH
DRUM PH #2
DRUM PH #1
Scotts Flat
32,000 AF
DUTCH FLAT PH #2
DUTCH FLAT PH #1
Rollins
66,000 AF
CHICAGO PARK PH
Deer
Cr
S
Combie
9,000 AF
HALSEY PH
Bear
R
WISE PH
NARROWS PH # 1&2
Marysville
1,000,000 AF
Camp Far West
103,000 AF
Feather
R
Lake Valley
8,127 AF
R
N Fk of N Fk American
N Fk American R
Duncan Cr Div
French Meadows
125,000 AF
R
American
N Fk Long Canyon Div
S Fk Long Canyon Div
FRENCH MEADOW PH
202,600 AF
Cr
Lake Edson
20,000 AF
Long Canyon Cr
Pilot
Cr
LOWELL L STEPHENSON PH
Ralston Interbay
Middle Fk
Rubicon R
Ralston Afterbay
OXBOW PH
RALSTON PH
AUBURN PH
South Canal
Nimbus
8,800 AF
FOLSOM PH
NIMBUS PH
Slab Creek
16,600 AF
CAMINO PH
S
Chili Bar
WHITE ROCK PH
CHILI BAR PH
Putah Cr
Lake Berryessa
1,602,000 AF
Putah Div
TRACY PUMPING PLA
20 MI
67 MI
DELTA
Rubicon
R
Buck Islan
Rockbound Lake
Rubicon
Cr
Gerle
Gerle Cr Div
ROBBS PEAK
Union
271,000
UNION VALLEY PH
Junction
S
Fk
Fk
Cr
Brush Cr Div
JAYBIRD PH
Camino
Silver
EL DORADO PH

a
V



Echo Lake
Medley Lakes
5,550 AF
Twin Lakes
21,581 AF
Truckee R
Pyramid Cr
Caples Cr
Silver Lake
11,800 AF
Cr
Silver
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
ELEVATION IN FEET
Rubicon R
Buck Island Div.
Loon Lake
76,500 AF
Rockbound Lake
Cr
Rubicon
Gerle
Gerle Cr Div
LOON LAKE PH#1
Robbs Forebay
Fk Rubicon R
S
Ice House
46,000 AF
Cr
R
ROBBS PEAK PH
Union Valley
271,000 AF
UNION VALLEY PH
Fk
Silver
American
Junction
S
Duncan Cr Div
French Meadows
125,000 AF
R
N Fk
Long Canyon Div
S Fk
Long Canyon Div
FRENCH MEADOW PH
202,600 AF
Cr
Lake Edson
20,000 AF
Pilot
Cr
Fk
Long
Canyon
Cr
Jenkinson Lake
41,000 AF
N Fk Cosumnes R
Brush Cr Div
JAYBIRD PH
Camino
L. L. STEPHENSON PH
Interbay
Fk
R
Silver
EL DORADO PH
Rubicon
Slab Creek
16,600 AF
CAMINO PH
S
Chili Bar
WHITE ROCK PH
CHILI BAR PH
Putah Cr
Lake Berryessa
1,602,000 AF
Putah Div
Canal
Nimbus
8,800 AF
FOLSOM PH
NIMBUS PH
TRACY PUMPING PLANT
20 MI
67 MI
DELTA

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY OPERATIONS OFFICE
WATER CONTROL BRANCH

SCHEMATIC PROFILE
SACRAMENTO-SAN JOAQUIN RIVER SYSTEMS
INCLUDING RESERVOIRS AND POWERPLANTS
SHEET 1 OF 2

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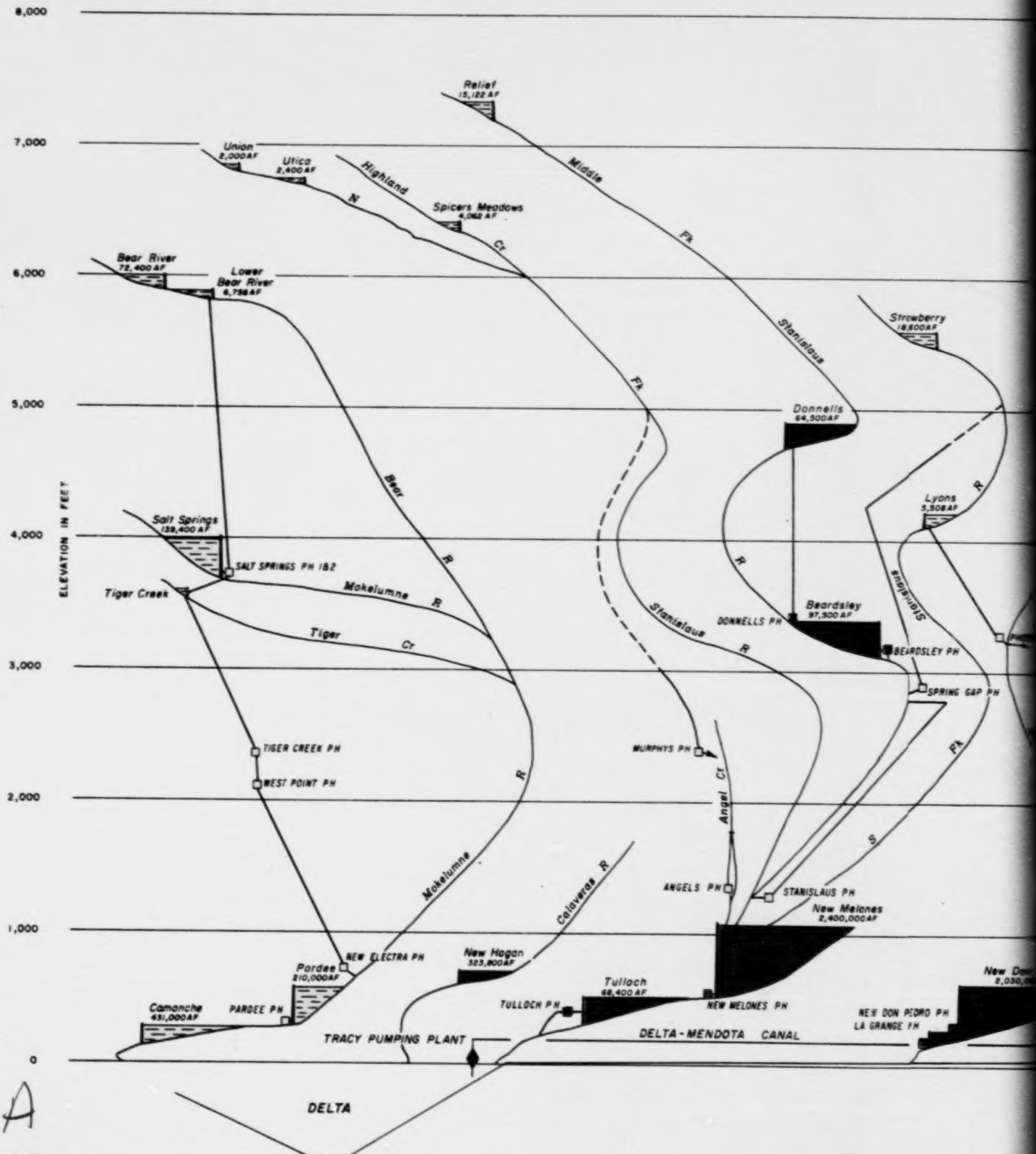
FIGURE 2


ELEVATION IN FEET
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Relief
15,122 AF
Union
2,000 AF
Utica
2,400 AF
Highland
N
Spicers Meadows
4,062 AF
Cr
Middle
Fk
Stanislaus
Bear River
72,400 AF
Lower
Bear River
6,758 AF
Fk
Strawberry
18,600AF
Donnells
64,500AF
Lyons
5,508AF
R
Bear
R
Salt Springs
139,400 AF
SALT SPRINGS PH 1&2
Tiger Creek
Mokelumne
R
Tiger
Cr
Stanislaus
R
R
Beardsley
97,500 AF
DONNELLS PH
BEARDSLEY PH
Stanislaus
SPRING GAP PH
Fk
TIGER CREEK PH
WEST POINT PH
R
MURPHYS PH
Angel Cr
S
Mokelumne
Calaveras R
ANGELS PH
STANISLAUS PH
New Melones
2,400,000AF
NEW ELECTRA PH
Pardee
210,000AF
New Hogan
323,800AF
Tulloch
68,400 AF
TULLOCH PH
NEW MELONES PH
New Don
2,030,0
NEW DON PEDRO PH
LA GRANGE PH
Camanche
431,000AF
PARDEE PH
TRACY PUMPING PLANT
DELTA-MENDOTA CANAL
DELTA

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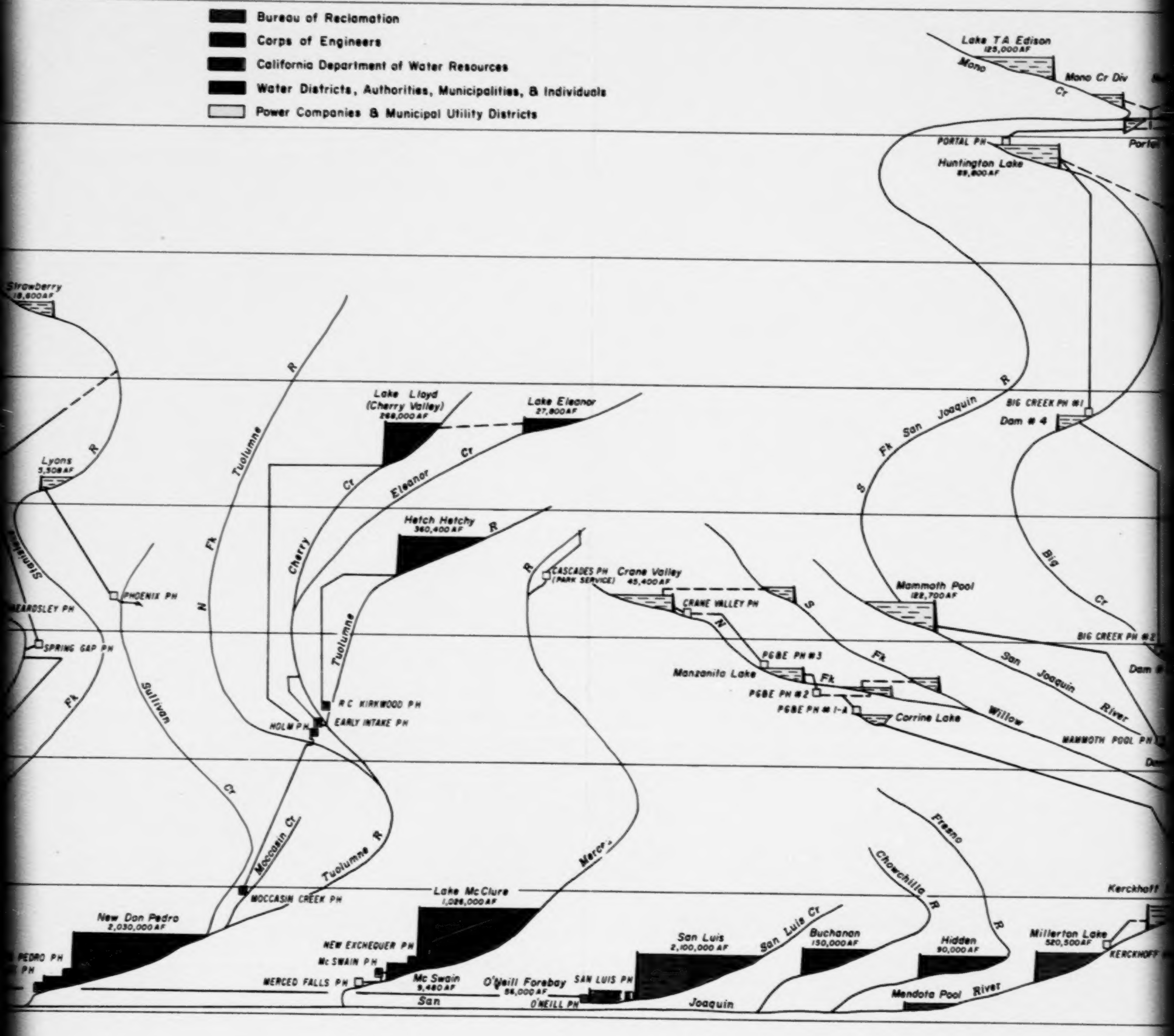
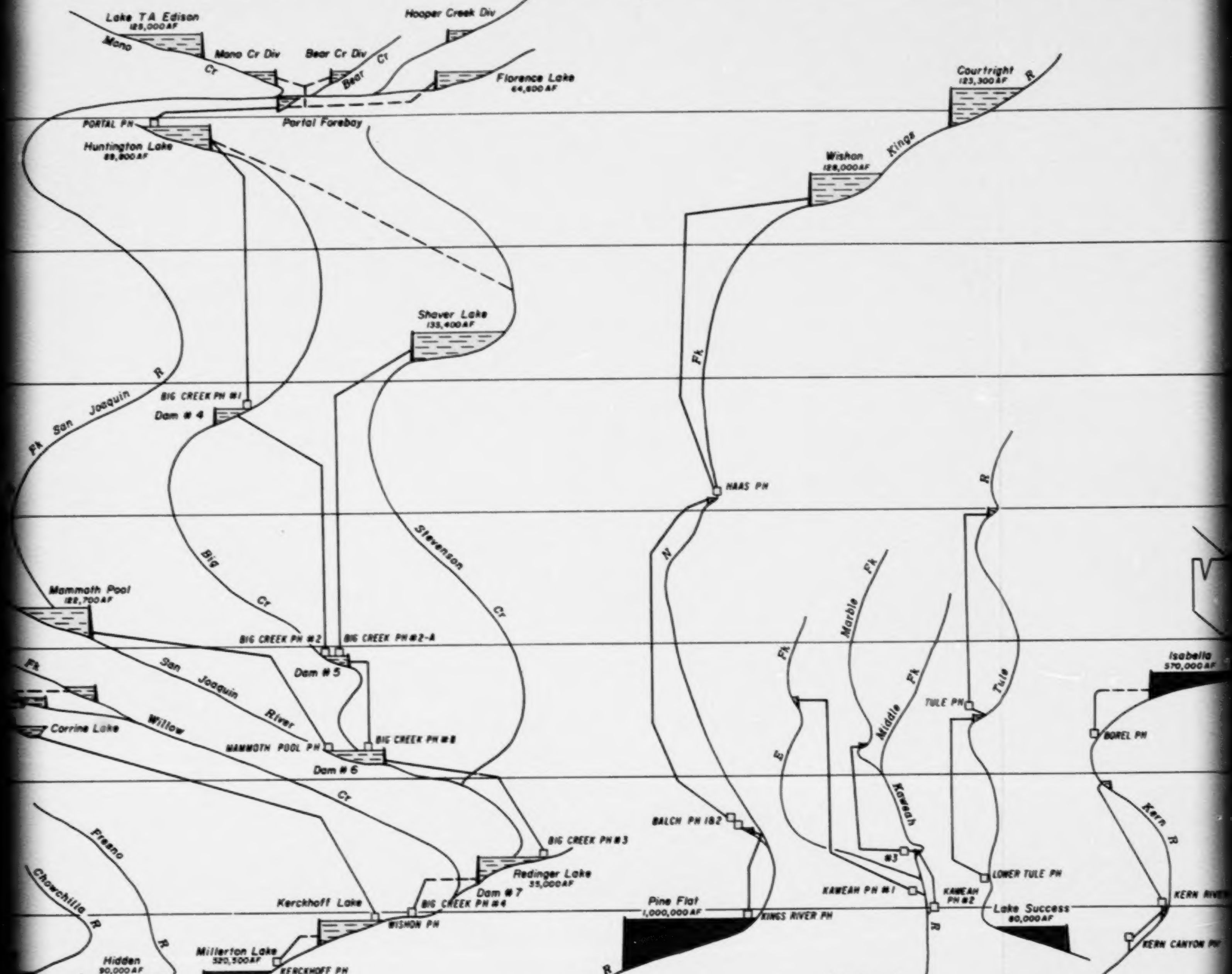

Bureau of Reclamation
Corps of Engineers
California Department of Water Resources
Water Districts, Authorities, Municipalities, & Individuals
Power Companies & Municipal Utility Districts
Lake T A Edison
125,000 AF
Mono
Cr
Mono Cr Div
PORTAL PH
Huntington Lake
89,800 AF
Strawberry
18,600AF
Lyons
5,508AF
R
Stanislaus
BEARDSLEY PH
PHOENIX PH
SPRING GAP PH
Fk
Sullivan
Cr
N
Fk
Tuolumne
R
Lake Lloyd
(Cherry Valley)
268,000 AF
Lake Eleanor
27,800 AF
Cherry
Cr
Eleanor
Cr
Hetch Hetchy
360,400 AF
R
Tuolumne
R C KIRKWOOD PH
EARLY INTAKE PH
HOLM PH
Moccasin Cr
Tuolumne R
MOCCASIN CREEK PH
New Don Pedro
2,030,000 AF
PEDRO PH
PH
R
CASCADES PH
(PARK SERVICE)
Crane Valley
45,400 AF
CRANE VALLEY PH
N
S
Fk
PG&E PH #3
Manzanita Lake
Fk
PG&E PH #2
PG&E PH # 1-A
Corrine Lake
Willow
S
Fk
San
Joaquin
R
Mammoth Pool
122,700 AF
San
Joaquin
River
MAMMOTH POOL PH
BIG CREEK PH #1
Dam # 4
Big
Cr
BIG CREEK PH #2
Dam
Merced
Lake McClure
1,026,000 AF
NEW EXCHEQUER PH
Mc SWAIN PH
MERCED FALLS PH
Mc Swain
9,480 AF
O'Neill Forebay
56,000 AF
O'NEILL PH
SAN LUIS PH
San Luis
2,100,000 AF
San Luis Cr
San
Joaquin
Buchanan
150,000 AF
Chowchilla R
Hidden
90,000 AF
Fresno
R
Mendota Pool
River
Millerton Lake
520,500 AF
KERCKHOFF
Kerckhoff

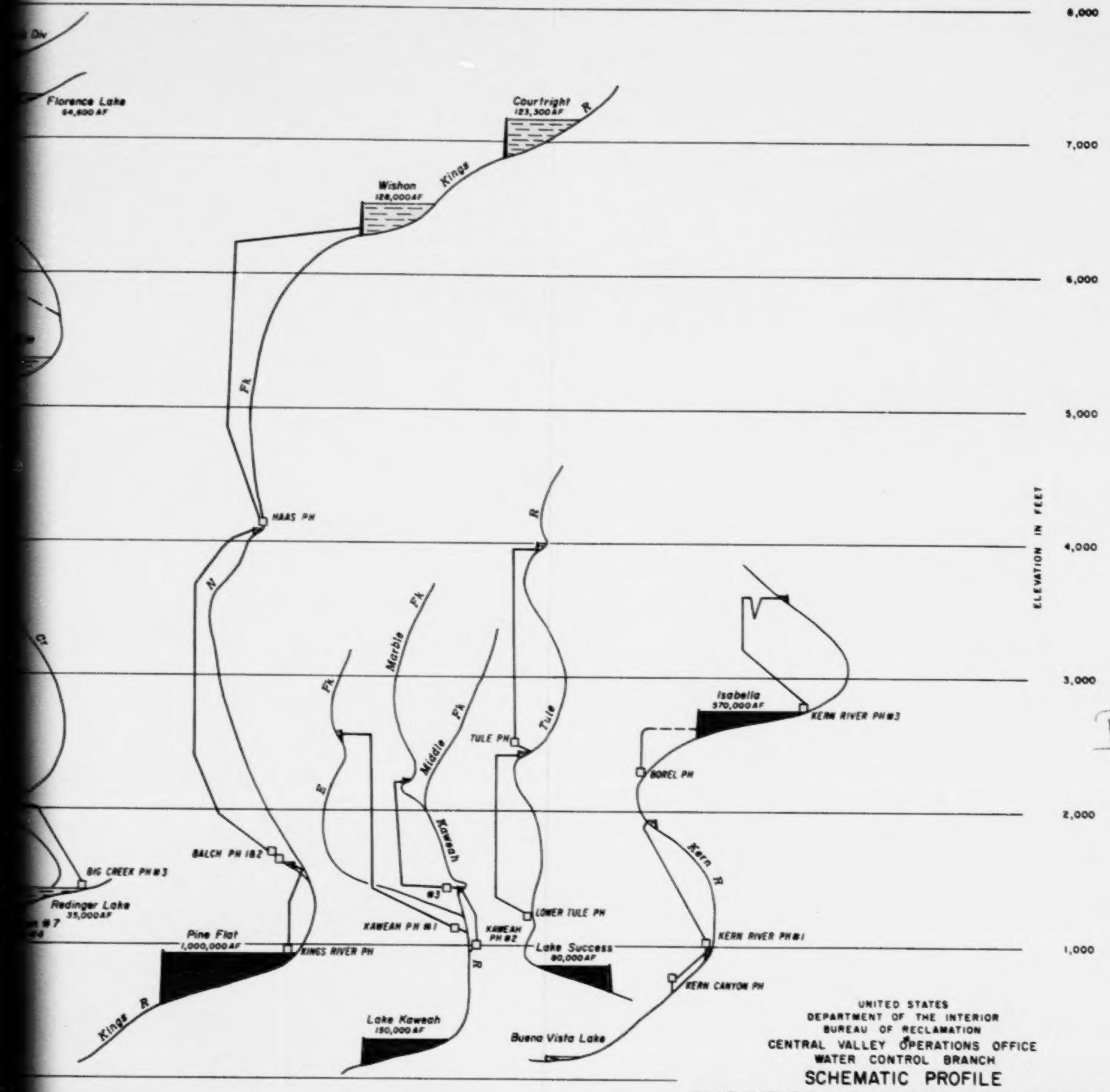
B


Lake T A Edison
125,000 AF
Mono
Cr
Mono Cr Div
Bear Cr Div
Bear
Cr
Hooper Creek Div
Florence Lake
64,600 AF
PORTAL PH
Portal Forebay
Huntington Lake
88,800 AF
Courtright
123,300 AF
R
Wishon
128,000 AF
Kings
Fk
Shaver Lake
135,400 AF
Fk San Joaquin R
BIG CREEK PH #1
Dam # 4
HAAS PH
N
Big
Cr
Stevenson
Cr
R
Mammoth Pool
122,700 AF
BIG CREEK PH #2
BIG CREEK PH #2-A
Dam # 5
San Joaquin River
Fk
Willow
Cr
Corrine Lake
MAMMOTH POOL PH
BIG CREEK PH #8
Dam # 6
Marble Fk
Fk
E
Middle Fk
Kaweah
TULE PH
Tule
Isabella
570,000 AF
BOREL PH
Kern R
Fresno
R
Chowchilla R
BIG CREEK PH #3
Redinger Lake
35,000 AF
Dam # 7
BIG CREEK PH #4
Kerckhoff Lake
WISHON PH
BALCH PH 1&2
#3
KAWEAH PH #1
KAWEAH PH #2
R
LOWER TULE PH
KERN RIVER
KERN CANYON PH
Pine Flat
1,000,000 AF
KINGS RIVER PH
Kings R
Lake Success
80,000 AF
Hidden
90,000 AF
Millerton Lake
520,500 AF
KERCKHOFF PH
Mendota Pool
River
Lake Kaweah
150,000 AF
Buena Vista Lake

SACRAM
INCLUDI

1

23


Div
Florence Lake
64,600 AF
Courtright
123,300 AF
R
Kings
Wishon
128,000 AF
N
Fk
HAAS PH
Cr
BALCH PH 1&2
BIG CREEK PH #3
Redinger Lake
35,000 AF
#7
Pine Flat
1,000,000 AF
KINGS RIVER PH
Kings R
Fk
Marble Fk
Middle Fk
Kaweah
#3
KAWEAH PH #1
KAWEAH PH #2
R
Lake Kaweah
150,000 AF
R
TULE PH
Tule
LOWER TULE PH
Lake Success
80,000 AF
Isabella
570,000 AF
KERN RIVER PH #3
BOREL PH
Kern R
KERN RIVER PH #1
KERN CANYON PH
Buena Vista Lake
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
ELEVATION IN FEET

D

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CENTRAL VALLEY OPERATIONS OFFICE
WATER CONTROL BRANCH

SCHEMATIC PROFILE
SACRAMENTO-SAN JOAQUIN RIVER SYSTEMS
INCLUDING RESERVOIRS AND POWERPLANTS
SHEET 2 OF 2

214-208-5229

FIGURE 2

streamflow and, to a large degree, water quality during the drier months of the year are dependent upon operation of upstream reservoirs, the net impact being beneficial or detrimental depending upon the circumstances in each case. Quality problems in San Francisco Bay are largely associated with the disposal of municipal and industrial wastes.

Tulare Basin

Major surface water quality problems have not generally been experienced in the Tulare Basin. The perennial streams which arise in isolated parts of the Sierra Nevada are not subject to major manmade waste loads, as most discharges are applied to the land. Irrigation return water forms a major portion of the summar base flow in the lower reaches of the larger streams. Saline water from oil wells is a contributor to the basin salt load.

Ground water near Tulare Lake has experienced an increase in dissolved solids concentrations over the years. In only a few locations has ground water been abandoned as a source as a result of quality degradation, but a potentially serious problem does exist if actions are not undertaken to establish a salt balance within the basin. In 1960, the unfavorable salt balance is estimated to have furnished an average of more than half a million tons of dissolved solids per year to basin soil moisture and ground water. Suitable salt levels in the root zone have been maintained by the practice of leaching dissolved solids downward.

Significant portions of the ground water exceed the recommended total dissolved solids concentration in the USPHS Drinking Water Standard.

Nitrate concentrations in some ground water in the Tulare Basin and elsewhere approach or exceed the levels recommended by the Drinking Water Standards. High nitrogen concentrations are usually attributed to sewage effluent and leaching of naturally occurring nitrogen and fertilizers. Since there is presently no economical way of removing nitrogen from large quantities of water, the problem is best avoided by adopting water development plans that do not provide municipalities with heavily recycled water. However, studies are underway to develop a feasible method of removing nitrogen from agricultural waste water.

Flooding of low lands during years of excessive runoff has increased the loss of resting water fowl due to outbreaks of botulism resulting in the death of several hundred thousand birds in a year.

Encephalitis is a significant problem with 12 cases in the 1962-66 period plus four other arthropod-borne cases. This basin had 234 of the 420 (56 percent) cases of encephalitis that occurred during the 1952 epidemic in the Central Valley. The potential for mosquito-borne diseases becomes especially acute during years of heavy runoff when floodwater is present in Tulare Lake and other portions of the valley floor. These conditions existed during the summer of 1969 but an extensive emergency mosquito abatement program throughout the Central Valley reduced the California encephalitis incidence to two cases. Eleven mosquito abatement districts in the basin spent over 2.3 million dollars during 1968-69, mostly on reduction from agricultural sources. An extensive effort will need to be maintained in the future since the vector potential will increase with irrigated acreage.

San Joaquin Basin

The major water quality problems of streams on the valley floor are large salt loads associated with irrigation and nutrients from municipal, industrial, and agricultural sources. Major portions of basin streams are reaching an undesirable state of nutrient enrichment. Prolific aquatic plant and algal growths are causing detriments to beneficial water uses. Aquatic plants have on occasion nearly blocked reaches of the lower Stanislaus River and have interfered with recreational uses. Diurnal fluctuation of dissolved oxygen due to the presence of large algal concentrations and partially treated municipal and industrial wastes have contributed to fish kills in the Stanislaus, Tuolumne, and San Joaquin Rivers. Other water quality problems include excessive coliform levels, pesticide concentrations, and turbidity.

The high salt concentrations in the lower reaches of the San Joaquin River and its major tributaries arise from upstream diversion of natural flow and the large volumes of drainage, waste waters, and return flows which, directly or indirectly, find their way into the surface drainage. Indeed the entire flow under certain conditions is comprised of used waters. It is estimated that the agricultural return water at present carries a total annual salt load of 740,000 tons to the Sacramento-San Joaquin Delta. A contributor to the salt load of the basin is the saline water from the abandoned gas wells on the Tuolumne River. The impact of this waste is such that the Tuolumne River at its mouth has about four times the salt concentration of similar adjacent rivers. Although the water in the lower San Joaquin River is still usable for agriculture most of the time, severe crop damage has been experienced upon occasion. Moreover, greater volume of applied water is needed to leach the greater amount of accumulated salts in the soil system. Increasing drainage problems have been associated with the increase in salt concentration. The general deterioration of San Joaquin River water quality might be exemplified by failure, during a recent 8-year historic period of average inflows, to meet the subsequently adopted State-Federal water quality standards near Vernalis during 43 percent of the calendar months.

Significant portions of the ground water in the basin exceed the recommended total dissolved solid concentrations in the Public Health Service Drinking Water Standards.

Many households in this basin, and the others, are served by individual septic tanks and leaching fields. There is an increasing need to connect these systems to community sewerage systems. Another problem not restricted to the San Joaquin Basin is associated with the disposal of waste water from the mountainous areas where large recreational populations exist during the summer and winter months. The diverse location of these small towns and recreational communities makes effective treatment difficult. Incipient eutrophication problems have been reported in nearby smaller reservoirs.

Sacramento Basin

Water quality problems associated with irrigated agriculture and municipal and industrial discharges are relatively minor compared with other parts of the Central Valley. This has resulted in part from the use of the Sacramento River to convey ever-increasing quantities of water developed within the Sacramento Basin or imported from the North Coastal Basin.

Drainage from abandoned mines and tailings has upon occasion caused severe local losses of fish in the upper watershed.

The Sacramento Basin had 57 percent of the encephalitis cases and 26 percent of other vector-borne diseases in California during 1962-66. Mosquito abatement districts are active in all of the valley counties. The total budget of almost 1.9 million dollars in 1968-69 comprised 23 percent of the State total. Most of the effort was on agricultural source reduction. An increase in irrigation or improperly constructed reservoir areas can cause a greater potential problem.

Delta-Central Sierra Basin

The present quality of the Delta waters is generally adequate in most respects to support all beneficial uses. Indeed, in some respects, water quality has improved significantly over the lowest quality experienced historically as the result of higher Delta outflows presently sustained from the Central Valley Project.

But while evidence of gross pollution has been largely eliminated, the recent extremely rapid growth in the tributary area population and industrial activity has left some problems unsolved and created new ones. The existing water quality problems of the Delta system may be categorized by (1) eutrophication and associated dissolved oxygen fluctuations, (2) suspended sediments and turbidity, (3) salinity, (4) toxic materials and, (5) bacteriological quality.

Eutrophication. The most serious enrichment problems in the Delta are found along the lower San Joaquin River and in certain localized areas receiving waste discharges but having little or no net freshwater flow. These problems occur mainly in the late summer and coincide with low riverflows, high temperatures, and the harvesting season when fruit and vegetable canneries are in full operation. Dissolved oxygen problems are further aggravated by channel deepening for navigational purposes. The resulting depressed dissolved oxygen levels have not been sufficient to support fish life and therefore prevents fish from moving through the area. In the autumn these conditions, together with reversal of natural flow patterns by export pumping plants, have created environmental conditions unsuitable for the passage of anadromous fish (salmon) from the Delta to spawning areas in the San Joaquin Valley.

Warm, shallow, dead-end sloughs of the eastern Delta support objectionable populations of planktonic blue-green algae during summer months. Of the many algal forms, the blue-greens are most frequently associated with nuisance conditions such as obnoxious odors resulting from decaying cells, and excretion of toxins harmful to animal life.

Floating and semiattached aquatic plants such as water primrose and water hyacinths frequently clog waterways in the lower San Joaquin River system during the summer. Extensive growths of these plants have also been observed in localized waterways of the Delta. These plants interfere with the passage of small boat traffic and contribute to the total organic load in the Delta-Bay system as they break loose and move downstream in the fall and winter months.

Suspended Sediments and Turbidity. Much of the water in the Delta system is turbid as a result of an abundance of suspended silts, clays, and organic matter. Most of these sediments enter the tidal system with the flow of the major tributary rivers. Some enriched areas are turbid as a result of planktonic algal populations, but inorganic turbidity tends to suppress nuisance algal populations in much of the Delta.

Continuous dredging operations to maintain deep channels for shipping has contributed to turbidity of Delta waters and has been a significant, but as yet unquantified, factor in the temporary destruction of bottom organisms through displacement and suffocation.

Salinity. At present salinity problems occur mainly during years of below normal runoff and in the eastern Delta are largely associated with the high concentration of salts carried by the San Joaquin River into the Delta. Operation of the State and Federal export pumping plants near Tracy draws high quality Sacramento River water across the Delta and restricts the low quality area to the southeast corner. Localized problems resulting from irrigation returns occur elsewhere such as in dead-end sloughs.

Salinity problems in the western Delta result primarily from the incursion of saline waters from the San Francisco Bay system. The extent of incursion is determined by the freshwater flow from the Delta to the Bay. Historical problems of incursion have been controlled since the completion of Shasta Dam by the availability of water in excess of the current demands upon the Central Valley Project.

Toxic Materials. Fish kills caused by toxic waste discharges have occurred at various times. Industrial wastes have killed large numbers of fish in localized areas, and agricultural pesticides have been responsible for fish kills in the Delta and other areas of the Central Valley. The majority of these kills were the result of accidental spills or discharges.

There has been some mortality among striped bass and other fishes during late spring and early summer for many years. The cause or causes are as yet unknown but seasonal changes in water quality and toxic pollutants are suspected.

Pesticides are found throughout the waters and bottom sediments of the Delta system. The more persistent chlorinated hydrocarbon pesticides are consistently found throughout the system at a higher level than the less persistent organophosphate compounds. The sediments having the highest pesticide content are found in the western Delta.

Pesticides have concentrated in aquatic life of the Delta. The long-term effects of pesticide concentrations found in aquatic life of the Delta are not known. The effects of intermittent exposure to toxic pesticide levels in water and of long-term exposure to these compounds and combinations of them are likewise unknown. Variations in species sensitivity complicate an evaluation of the pesticide threat.

Bacteriological Quality. Bacteriological quality of Delta waters, as measured by the presence of coliform bacteria, varies depending upon proximity of waste discharges and significant land runoff. Generally speaking, the highest concentration of coliform organisms are found in the western Delta. Local exceptions to this can be found in the vicinity of major municipal waste discharges. For example, near Stockton over half the samples taken in a recent survey were in violation of the established water quality standard of 200 fecal coliforms per 100 ml.

San Francisco Bay Basin

Municipal, industrial, and agricultural water supplies for a portion of northern Contra Costa County are derived from waterways of the western Delta and eastern Suisun Bay. Due to salinity incursion, at least one municipal supply has been periodically abandoned for other more expensive sources during the summer low-flow period.

Depressed levels of dissolved oxygen in the extreme portions of South San Francisco Bay occur during the late summer and early fall months due to municipal waste discharge. Dissolved oxygen deficiencies also occur in the Petaluma and Napa Rivers. Algal growths have caused complete lack of dissolved oxygen in the extreme reaches of some tidal sloughs, creeks, and rivers, and have caused pH values up to 9.0. Green seaweed along mudflats are particularly apparent throughout the Bay system during the summer and fall when decomposing mats emanate hydrogen sulfite. Recent years have brought red water discoloration caused by marine ciliate, a phenomenon probably aggravated by high nutrient concentrations.

Fish kills have occurred in the Bay system as the result of accidental spills of toxic materials and inadequately treated sewage and industrial waste discharges. Localized fish kills involving large numbers of striped bass have occurred in Suisun Bay from unknown causes.

Pesticides in the Bay system originate from municipal storm sewer and sanitary sewerage systems, urban runoff, and drainage from the vast agricultural lands in the Central Valley. The presence of these pesticides is as yet a threat of unknown magnitude to the fisheries and wildlife resources.

Limited data are available on the effects on water quality by discharges from combined sewer systems and bypasses of sewage from sanitary sewer systems overloaded because of storm water, and the discharge of storm-water runoff. Nevertheless, obvious visual problems are the direct result of such discharges.

The San Francisco Bay area has experienced oil pollution problems mainly localized at refinery docks, ports, marinas, and near storm sewer outlets attributable to accidental spills, deliberate discharges, pipeline leaks, and pumping of oil bilge or ballast water. During the period of January 1968 to June 1969, 235 oil spills were reported in San Francisco Bay from all sources.

Extensive recreational use is made of the waters of San Francisco Bay. Much of the Bay contains coliform bacteria levels greater than those recommended for water contact sports. Substantial improvement has been reported since initiation of chlorination of the discharge from a large municipal sewerage system.

There is no commercial oyster industry in San Francisco Bay although it wasathriving business at one time. There is sport clamming although coliform bacteria concentrations are higher than the Public Health Service and State allowable limits. At present portions of the Bay system are quarantined by the State Department of Public Health for harvesting shellfish for human consumption.

WASTE HANDLING SYSTEMS

Municipal

Municipal sewerage is provided to over 70 percent of the total Sacramento Basin population. There are more than 80 municipal sewage treatment plants providing treatment to a daily influent load of about 1.1 million PE (population equivalent). A summary of existing municipal sewage treatment facilities for all basins is shown in table 6. The total organic municipal waste load is reduced by about 47 percent, thus an effluent load of about 545,000 PE is discharged to waters of the Sacramento River system except for those amounts applied to land. The largest sewage treatment facilities are located in the Sacramento metropolitan area where more than 50 percent of the total population of the basin is located.

In the Delta-Central Sierra Basin, municipal sewerage is provided to more than 90 percent of the population. The total municipal waste load is reduced on the average by about 75 percent leaving an effluent load of about 120,000 PE. More than 30 percent of the load is discharged to surface waters and the remainder to land.

In the San Joaquin Basin, municipal sewerage is provided to less than 45 percent of the population. There are more than 47 municipal sewage treatment plants providing treatment to a daily load of about 230,000 PE. Municipal waste strength is reduced by about 77 percent leaving an effluent load of about 54,000 PE.

Table 6. Municipal treatment facilities

Basin	Treatment type	Number	Influent load		Flow (m.g.d.)
			PE (1,000)	Basin total (Percent)	
Sacramento	Lagoons	9	48	4.6	6.5
	Primary	13	625	60.5	50.0
	Primary with ponds	22	68	6.6	7.5
	Secondary	38	290	28.3	36.2
Delta-Central Sierra	Lagoons	6	4.5	0.9	0.7
	Primary	7	33	6.9	3.4
	Primary with ponds	13	65	13.6	5.3
	Secondary	12	376	78.6	27.6
San Joaquin	Lagoons	3	34	14.8	2.8
	Primary	6	19	8.3	2.3
	Primary with ponds	16	34	14.9	6.4
	Secondary	22	142	62.0	22.8
Tulare	Lagoons	2	8	1.1	0.4
	Primary	8	18	2.5	1.9
	Primary with ponds	18	260	36.8	20.4
	Secondary	36	420	59.6	33.4
San Francisco Bay	Primary	40	2,800	51	230
	Secondary	50	2,700	49	185

About 30 percent of the treated effluent flow is applied on land or percolation ponds, and the remainder is discharged to surface waters. The largest sewage treatment facilities are located at Madera, Merced, Modesto, and Turlock. These four plants provide secondary treatment for about 50 percent of the total sewage flow of the basin.

There are 64 municipal sewage treatment plants in the Tulare Basin providing treatment to a daily load of about 700,000 PE. The total municipal waste load is reduced on the average by less than 80 percent and an effluent load of about 140,000 PE is discharged to receiving waters or land. The total average daily flow of municipal waste is about 55 m.g.d., almost all of which is discharged on land and is available for reuse. Four major plants located in Fresno and Bakersfield receive and treat about 45 percent of the total population equivalent load and flow reaching municipal sewers of the basin.

In general, treatment practices in the San Francisco Bay Basin are barely adequate to conform with the needs of this densely populated area. There are 90 municipal sewage treatment plants providing treatment to a daily load of about 5.5 million PE. Many of the dischargers to the Bay system are under orders from the State regulatory agency to improve treatment or seek other points of discharge. The total municipal waste load is reduced by about 50 percent and an effluent load of 2.75 million PE is discharged to receiving waters. The total average daily flow of municipal waste is about 415 m.g.d. and of this total about 390 m.g.d. is discharged into marine waters or into streams which are under tidal influence. The remainder of the flow is discharged into inland fresh waters or applied to land in some locations. Five large treatment plants receive and treat more than 50 percent of the total sewage flow and equivalent load of the basin (234 m.g.d.).

During late summer and early fall of dry years, water has been released from the Delta-Mendota Canal to relieve the pollutal blockage of the San Joaquin River near Stockton to assist the migration of salmon to their spawning areas. The water quality problem arises as a result of various waste discharges, alterations of the hydrologic regime, and certain natural phenomena.

Industrial

Sacramento Basin. There are more than 1,100 manufacturing units employing more than 62,300 workers in the basin. More than 50 major facilities not including mines and sawmills have separate waste disposal facilities. Fruit and vegetable canning, fruit dehydration plants, olive processing, slaughter houses, dairies, and pulp and papermills are major industrial waste producers. Waste flows not discharged to municipal systems average 50 m.g.d. for food and kindred products and 60 m.g.d. for wood, paper, and pulp industry.

Many of the smaller food processing plants, mainly fruit dehydrators and packing plants, apply untreated effluent on land for percolation and evaporation. The remaining food and kindred product industries generally use ponds for treatment. Several of the large canneries discharge wastes to surface waters. The two sugar refineries are able to dispose of their entire waste in percolation and evaporation ponds without overflows. The two major pulp and paper industries provide secondary treatment with ponds before discharging treated effluent into the Sacramento River.

Industrial wastes particularly from food and kindred products industry are a major source of thermal discharges to basin streams.

The lumber, wood, paper and pulp industry is another major source of waste with more than 40 sawmills located in the basin. Sprinkler systems are gradually replacing log ponds which have been a source of pollution in the past. Two major paper and pulp plants are located on the banks of the Sacramento River.

Leaching from abandoned mines in the Spring and Squaw Creek areas in the Upper Sacramento River Basin have caused problems in the past. Partial control of the high concentrations of toxic metals from Spring Creek has been made possible with the construction of Spring Creek Debris Dam.

Delta-Central Sierra Basin. Industrial waste handling in this basin is very similar to that in the Sacramento Basin. There are more than 600 manufacturing units employing about 25,000 workers. The major industrial waste loads are from the food, chemical, and paper industries.

Heat loads from thermal-electric plants and municipal and industrial wastes are the major source of thermal discharges.

San Joaquin Basin. Within the basin there are more than 350 manufacturing plants employing over 20,000 people during the peak of activities. The canning and frozen food, poultry, and dairy industries are primary sources of industrial waste. Other large industrial waste sources include dairies, wineries, two sugar refineries, and several slaughter houses. Lumber and wood products, manufacturing, and mining industries are also present.

Much of the industrial waste produced is discharged to municipal sewers although separate discharges are made by several food products plants. Fruit and vegetable and poultry processing plants are a major source of industrial wastes from separate discharges. Secondary treatment is provided in almost all cases. A large fraction of this effluent load reaches surface waters.

Cooling and processing water from the canning of fruits and vegetables are the major industrial heat sources, and maximum impact on the waste handling system occurs during the peak harvesting season from July to September.

Tulare Basin. Significant waste loads are produced by more than 1,400 manufacturing units employing more than 35,000 workers. About 500 facilities do not discharge to local municipal sewers but have separate waste disposal facilities from which a daily load of about 200,000 PE is discharged in flows up to 18 m.g.d. during the peak of the crop processing season. This flow does not include the large volume of brine waste produced from oil fields. In addition to these separate discharges, it is estimated that about 200,000 PE of industrial waste is included in the effluent from municipal plants.

The major industrial waste sources are the food product industries (7.5 m.g.d.), petroleum refineries (10 m.g.d.), and chemical and allied products (1.0 m.g.d.). With the exception of some oil field brines which are injected into deep aquifers, most waste flows finally pass to land percolation and evaporation.

Basin heat loads are primarily from cooling waters used in food processing, wineries, and oil refineries. As waste is usually applied on land, only a very minor portion of heat load reaches surface waters.

San Francisco Bay Basin. As there are over 5,750 manufacturing industries employing 372,000 persons in the basin, industrial wastes constitute a major pollutional source. There are more than 80 large industrial plants which are not connected to municipal sewers but have in-plant collection and treatment facilities and separate outfalls, with an estimated daily load of about 800,000 PE discharged. Total daily industrial waste flow is about 75 m.g.d., exclusive of cooling water used at thermal-electric plants and oil refineries. A summary of industrial waste discharges from separate outfalls for the basic industrial categories is:

Food and kindred products	23 m.g.d.
Paper and allied products	40 m.g.d.
Petroleum refining	380 m.g.d.
Chemicals	50 m.g.d.
Primary and fabricated metals	20 m.g.d.

Thermal waste, including four major thermal-electric plants, is of major significance to receiving waters. The heat flux from these four plants requires more than 2,800 m.g.d. of cooling water. Loading from industrial waste sources are primarily cooling waters used in food processing, chemical industry, and petroleum refinery operations. Cooling water requirements of petroleum refineries total about 375 m.g.d.

Agricultural

Although animal waste loads are distributed throughout the Central Valley, the over 200 feedlots are responsible for some localized water quality problems. Valley waste loads from confined animals are of the same order of magnitude as the total municipal and industrial waste load before treatment. Most of the manure is used on land for agricultural purposes; however, large nutrient loads are carried by the valley streams and ground-water system.

Surface and subsurface drainage from irrigated lands is necessary to maintain continued productivity, but these waters constitute a major waste source in the Central Valley. These wastes typically reach the nearest surface channel by surface runoff, subsurface percolation, or in certain instances by collection in tile drains and pumping.

An agricultural drainage system is being constructed as part of the San Luis Unit of the Central Valley Project. With the exception of wastes to be carried by this system, agricultural wastes in the Tulare Basin will continue to accumulate in the ground-water soil moisture system.

Except in the Tulare Basin, the agricultural waste waters subsequently flow toward the ocean. Thus, the natural stream system largely comprises the waste handling system.

The surface and ground-water flow through the Central Valley and San Francisco Bay to the ocean is actually the ultimate carrier of all waste effluents from municipal, industrial, and agricultural sources. Water quality problems have arisen in those instances where sufficient flow of high quality dilution water has not been maintained to carry this load.

WATER RESOURCE MANAGEMENT CONSIDERATIONS

Evaluation of the present status of water development and water quality problems, together with the prospects for the future, must consider in part various legal, administrative, and institutional factors. Brief mention will be made here of certain aspects of the State-Federal water quality standards and State water rights law. A more exhaustive treatment of certain aspects of the situation is available.

Water Quality Considerations

Water quality factors can constrain water use although the critical factors will vary from use to use. Water quality criteria compatible with various uses have been developed for (1) public water supply, (2) industrial water supplies, (3) agricultural uses, (4) fish, other aquatic life and wildlife, and (5) recreation and aesthetics.

The characteristics and concentrations of substances in public water supplies should allow the production of a potable water, after treatment, which meets the criteria in U.S. Public Health Service Drinking Water Standards.

Water quality requirements for industrial water supplies differ so widely that no one set of meaningful water quality criteria are applicable. Furthermore, water treatment technology permits the utilization of nearly any source although at some variance in cost.

The utility of a water supply for agricultural purposes is associated with water quality. However, universal limits on the permissible concentrations of salts in irrigation water cannot be fixed for several reasons: (a) the soil solution is normally at least 3 to 8 times as concentrated as the water that replenishes it; (b) there is no definite relationship between the composition of the irrigation water and that of the soil solution; (c) plants vary widely in their tolerance to total salinity and specific salts; (d) soil types, climatic conditions, such as rainfall, temperature and humidity, and irrigation practices may all influence the reactions of the crop to the salts; and (e) interrelationships between and among constituents may be highly significant.

Good drainage of the soil may be as important for plant growth as a low irrigation water salt content. Even when excellent waters are used, poorly drained land may go out of production while highly saline waters can sometimes be successfully used on open well drained soils.

Aquatic environments support diverse life forms; however, the character of the water and the bottom sediments relate directly to the kinds of life found. Water quality objectives such as dissolved oxygen requirements are needed for nearly all aquatic life while specific criteria for salinity or other parameters may apply only to certain species or life stages. Examples of such criteria are found in the California Department of Fish and Game contributions to the San Francisco Bay-Delta Water Quality Control Program and the Water Quality Control Policies for the Bay-Delta area and major salmon and steelhead spawning reaches of the north coast such as the Klamath River.

Wildlife such as waterfowl have indirect water quality requirements; these include salinity criteria needed to support desirable grasses and other wetland vegetation used for bird food. Studies of plant foods and water quality have been performed by the California Department of Fish and Game.

The most difficult water uses to relate directly to water quality are probably those related to human recreational activity and aesthetics appeal. Gross pollution such as created by inadequately treated sewage or trash obviously impair these uses. More subtle changes such as incremental increases in turbidity, color, temperature, or enrichment with excessive algal populations are less clearly related to the social acceptance of water. Other criteria include visibility requirements for skindiving and the effect of aquatic plant encroachment on shoreline recreational uses.

State-Federal Water Quality Standards

The Water Quality Act of 1965 (PL 89-234) amended the Federal Water Pollution Control Act to provide for establishment by the states of water quality standards for interstate and coastal waters and for such standards becoming the applicable Federal water quality standards following a determination by the Secretary of Interior that they are consistent with the purposes of the Act. Standards adopted by the State of California were approved with certain exceptions and conditions on January 9, 1969. Included are standards for Tidal Waters Inland from the Golden Gate and for the Sacramento-San Joaquin Delta.

Adequate water quality criteria are set to protect identified beneficial uses with certain exceptions. The Secretary did not approve the temperature criteria for the Bay (and other waters) because they did not provide numerical limits deemed essential for effective administration. With respect to the implementation plan for San Francisco Bay, the Secretary made the following statement in approving the California standards: "I have approved the Water Quality Control Policy for the San Francisco Bay area on the basis that the soon-to-be completed Bay-Delta study will lead to the development of a detailed implementation plan for better waste treatment and control than that now being accomplished and required."

The beneficial water uses to be protected in the Sacramento-San Joaquin Delta include:

Domestic and municipal supply
Agricultural supply
Industrial supply
Propagation, sustenance and harvest of fish,
aquatic life, and wildlife
Recreation
Aesthetic enjoyment
Navigation

The Sacramento-San Joaquin Delta standard, with two exceptions, includes adequate water quality criteria for the protection of all present and potential water uses. The temperature criteria do not incorporate numerical limits and therefore were excluded from the Secretary's approval.

The matter of establishing salinity criteria supplemental to the initial Delta water quality standards received considerable attention from both the Department of Interior and the State Water Resources Control Board. The State Board has recognized the need for further consideration of standards pertaining to the unprotected beneficial uses of striped bass spawning and municipal, industrial, and agricultural water uses of the western Delta, and committed itself to considering additional water quality objectives for the Delta after an additional hearing on water rights in the Delta. This hearing commenced on July 22, 1969, and is expected to be completed in the spring of 1970.

The Secretary of Interior approved the Delta mineral quality standards (Appendix 3) on the basis of the State's commitment on this matter.

Until September 30, 1972, the Bureau of Reclamation will operate the Central Valley Project and related water projects that affect Delta water supplies to conform with the recommendations of a Department of Interior task force, including paragraphs B-2 related to striped bass spawning and B-5 related to water supplies in the western Delta (Appendix 3). Such operation is inteded to maintain existing water quality during an interim period and in effect protect beneficial uses not covered by existing water quality standards.

That part of the Water Quality Standards (State Board Resolution 68-16) for the entire State concerned with waters presently having high quality contains in part the following policy statement:

> "Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies."

Water quality standards are being developed by the State for various instrastate waters. Within the Central Valley, several policies have been adopted for tributary streams and others for the mainstem Sacramento and San Joaquin Rivers are in tentative form.

A summary of selected criteria from water quality standards for Central Valley streams and adjacent waters is presented in table 7.

Existing Contractual Water Quality Commitments

In the plan formulation for the Central Valley Project, water quality objectives and the flows needed to achieve them have been given continuing consideration for about the last 40 years. On the basis of these studies, contractual commitments were established for the Delta-Mendota and Contra Costa Canals.

In addition to these Federal commitments, the State Water Project has included water quality limitations in its water service contracts. Because of the physical relationship between the canals and the Sacramento-San Joaquin River Delta area, other Federal and State commitments for contractual quality of water objectives are being negotiated for the Delta area.

Present water quality contract requirements of the Bureau of Reclamation are:

Delta-Mendota Canal	Maximum total dissolved solids (p.p.m.)
Calendar year, annual average	450
Calendar month, average	600
Daily, average	800
5-year average	400
	Maximum chlorides (p.p.m.)
Contra Costa Canal	250

The State of California has the following water quality limitations for selected constituents in its water supply contracts:

	Maximum concentration (p.p.m.)	
	Monthly average	Average for any 10-year period
Total dissolved solids	440	220
Total hardness	180	110
Chlorides	110	55

No reduction in water quality objectives is provided for in critically dry years. Provision is made for shortages in quantity delivered under some agricultural contracts, however.

State Water Quality Authority

On January 1, 1970, the Porter-Cologne Water Quality Control Act became operative. This Act, considered by the State to be the

Table 7. Selected criteria from water quality standards for Central Valley streams and adjacent waters

Location	Standard	Criteria, mg/1 Dissolved Oxygen	 Total Dissolved Solids	 Nitrogen
Sacramento-San Joaquin Delta				
San Joaquin River at Vernalis	Interstate	5.0	500	3.0
San Andreas Landing in San Joaquin River	Interstate	5.0	[1]	1.0
San Francisco Bay tidal waters	Interstate	5.0	500[2]	2.0[3]
American River below Folsom Dam	Intrastate	7.0[4]	125	1.0

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[1] Criteria of 450 p.p.m. annual mean, 500 p.p.m. monthly mean and 700 p.p.m. 10-day mean applies also to three other Delta locations.

[2] Within 2,000 feet of diversions when tidal waters are used for domestic water supplies.

[3] East of Carquinez Strait.

[4] 5.0 mg/1 in reach between Watt Avenue Bridge and Sacramento River.

most comprehensive water quality control law in the nation, completely revises the State's water pollution and water quality control laws and also provides for procedures whereby the State Water Resources Control Board may carry out water quality objectives through its water rights function. The Act continues the unique organizational arrangement of nine regional boards and the State Water Resources Control Board as the State water quality control agencies and directs "That the statewide program for water quality control can be most effectively administrered regionally, within a framework of statewide coordination and policy."

Changes in definitions which put a stronger emphasis on water quality aspects include the broadening of the definition of "beneficial uses" to include "aesthetic enjoyment" and "preservation and enhancement of fish, wildlife, and other aquatic resources or preserves." "Nuisance" is expanded to include problems caused by treatment as well as a result of waste discharges. "Person" now includes the United States to the extent authorized by Federal law.

The State Board is directed to adopt a State policy (after a public hearing) for water quality control which may include (a) water quality principles and guidelines for long-range resource planning, including ground-water and surface water management programs and control and use of reclaimed water; (b) water quality objectives at key locations for planning and operation of water resource development projects and for water quality control activities; (c) water quality control plans adopted by the State Board for interstate or coastal waters or other waters of interregional or statewide interest; (d) other principles and guidelines deemed essential by the State Board for water quality control. This policy must be complied with by all other Government entities including the regional boards.

After a public hearing, the boards are directed to adopt regional plans for water quality control. Each regional plan must contain beneficial uses to be protected, objectives (levels of water quality constituent needed to protect beneficial uses) and a program of implementation. Plans must be approved by the State Board.

A regional board has essentially complete jurisdiction over all waters within its region in matters pertaining to water quality. The chief regulatory instrument of the RWQCB is through issuance of waste discharge requirements. These requirements may be reviewed and revised by the RWQCB at any time.

Water Rights Considerations

Water laws in California have evolved over a period well in excess of 100 years and are exceedingly complex. California recognizes two doctrines--the riparian and the appropriative--as governing water rights and these exist simultaneously and often in conflict. These laws, including interstate compacts, were until 1968 almost universally couched in terms of quantity only. The water uses for which water may be appropriated and a water right established include withdrawal and instream water uses--domestic use being highest, followed by agricultural, where conflicts exist. However, once an application has progressed through the necessary legal phases and a proven right or license is granted without restrictions or conditions, the right issued to a low preference use cannot be reassigned to a higher preference use without condemnation and compensation.

With the possible exception of some of the streams in the north coastal region of California, existing natural flow withdrawal rights equal or exceed the total natural flow of the streams during the summer months. Such rights were generally established prior to 1920 and it is believed they exist as proven or fully established rights. In some streams, demand by the withdrawal uses, supported by existing established natural flow and storage rights, in combination with applications, may exceed the total average annual natural yield of the streams.

Each appropriative right has a date of priority. With certain statutory exceptions, this time priority gives preference in the use of water to the earlier rights when the supply is not enough for all. During dry years, the flow in some streams during the critical low flow period are such that only riparian rights are eligible to divert water.

While the State water right laws now recognize that recreation and fish and wildlife are beneficial uses of water, they do not include effective provisions or mechanisms for the establishment of water rights for the maintenance of minimum streamflows required to support these instream uses as against established rights to divert. Rights to withdraw water from streams for use by recreation resorts, fish hatcheries, commercial fish and wildlife farms may be obtained. Nautral flow and storage rights for the purpose of generation of hydroelectric power can also be legally obtained.

Since 1927, the State legislature has granted authority to a State administrative agency to file applications to appropriate rights to all surface waters in the State to which proved rights have not previously been established by private parties or public agencies.

This administrative agency has the right to hold such filings in trust for possible release or assignment to such parties and agencies in a manner consistent with a systematic and planned development of the water resources of the State. Such release or assignment is made for projects which (a) are not in conflict with a general and coordinated plan for water development, and (b) will not deprive a county of origin of any water necessary for ultimate development of the county.

The whole area of water rights and water use is very complex, highly competitive, and emotionally charged. It is also a very politically sensitive area in the controversial State versus Federal rights arena.

Superimposed upon and reinforcing the legal framework of water resource development is a system of social mores, or ethics, economic principles and evaluation methodologies or procedures. This system has been evolving since about 1850 and up until about World War II it worked rather well--the primary force and basis of economic development of the arid west. The primary objective at this time was water resource development for irrigation water supplies and was pursued by private, local public, and Federal interests. With the exception of the Los Angeles and San Francisco metropolitan areas, the quantity of municipal and industrial water supplies needed were relatively negligible and easily satisfied. Use of water for recreation, fishery, and wildlife as a consideration in water resource development was unheard of, for all practical purposes. These uses were incidental. They could be accommodated as long as their use did not interfere with attainment of the basic objective.

World War II provided a powerful stimulus to industrial development in California which has since continued. Urban populations expanded rapidly. Markets under the influence of population growth and increasing affluence stimulated the demand for agricultural commodities and for irrigation water. Additional municipal and industrial supplies were needed. To meet the demand, water resource development was sharply expanded including mammoth projects involving large dams, transbasin diversions, and transportation networks extending over hundreds of miles.

However, certain vital weaknesses in this system became apparent. It failed to consider the adverse effects of deterioration in water quality on downstream withdrawal uses, primarily agriculture, located in nonproject service areas. It failed to consider the adverse effects on nonwithdrawal beneficial uses of water in terms of both streamflow depletions and quality deterioration. It failed to fully consider the adverse effects of construction and operation of project physical facilities in a whole spectrum of land and water uses.

Wastes from municipalities, industrial activity, and irrigated agriculture together with some water resources developments, were associated with acceleration of the deterioration in water quality and continued depletion of the fishery, wildlife, and recreational resources of the streams, which had been in progress for many years. At the same time, the demand for these uses and values, emanating primarily from the growing urban areas, was rapidly increasing. Other parts of the nation were experiencing somewhat similar problems and a general national movement developed. Numerous Federal laws were passed to correct the situation including the Federal Water Pollution Control Act, Fish and Wildlife Coordination Act, and the Federal Water Project Recreation Act. In the west, these Federal Acts were enthusiastically supported by the conservation groups and generally by all groups. Significant portions of total project costs are now allocated to fish and wildlife, and recreation. Allocations of the water developed by the project, however, have not been proportionate with cost allocations since the total supply, almost without exception, continues to be allocated to agriculture and M&I uses. However, agreements are entered into with respect to releases from storage reservoirs to maintain the fishery and recreation. They do not, however, appear to have any legal standing in terms of water rights. These uses can be accommodated as long as supplies surplus to the demand of the withdrawal uses are present, and/or as long as the streams considered are used as conveyance systems for water to be withdrawn at a downstream point.

It is apparent that legal and public policy criteria for formulating and evaluating water resource projects have changed significantly over the last several years and further evolution can be expected in the immediate future. Reformulation or modification of projects conceived to satisfy less demanding criteria has been and will continue to be necessary. Such changes may be applicable to both authorized and yet to be authorized projects. To the extent that imposition of additional water supply, operational, water quality or other requirements upon authorized projects impairs the ability to meet present obligations, appropriate compensation, alternatives or other relief may be required. Future federally financed projects will be operated to meet established State and Federal water quality standards. The State should also move forward in imposing the same requirements upon operation of nonfederally financed projects.

Planning Coordination

Water resources development is a dynamic activity with methods and purposes constantly changing and under continuous reanalysis. For example, initial legislation had authorized that the Central Valley Project be designed to serve six purposes in three orders of priority, "first, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic uses; and third, for power." Present Federal policy, however, gives equal status and consideration in project plan formulation to these functions as well as to fishery, wildlife, recreation and water quality enhancement, industrial uses and preservation of unique natural areas.

To provide balanced development for these varied purposes, cooperation and coordination of Federal, State, local governments and private organizations will be needed. Many of the institutions needed to coordinate public and private activities already exist. While institutional relationships and activities are complex and seemingly independent, they are in fact substantially coordinated in California. The four principal construction agencies, the Bureau of Reclamation, the Corps of Engineers, the Soil Conservation Service, and the State Department of Water Resources, cooperate and coordinate their planning efforts through the California State-Federal Interagency Group. This group provides guidance in joint Federal-State planning activities to prevent duplications of effort and foster better cooperation. Other Federal and State agencies also now participate in the planning process. As cooperation and coordination improve and expand, better development will naturally evolve.

In practice, the State Resources Agency is actually the dominant agency in control of water resources development in California. Through its State Water Resources Control Board and Department of Water Resources, it coordinates planning by others to insure timely development of the State's water resources and conformance of such plans with the comprehensive California Water Plan.

Under the Water Resources Planning Act of 1965, Congress established the Water Resources Council with responsibility for maintaining a continuing assessment of the Nation's water resources and water requirements and promote broad interagency coordination at all levels of government in the interests of regional development in the overall national interests. The California Region Framework Study, now nearing completion, is a Federal-State multiagency effort to develop a comprehensive water resources development plan for the Council's guidance.

Neither the California Water Plan nor the Framework Plan are intended to be the last word in California water resources development, but rather are to serve as guides and a first step to more detailed studies and programs. Continued updating of plans and their implementation will require a joint effort of public agencies and private organizations interested in water resources development in California.

IV. FUTURE CONDITIONS

Projections of economic development and water use patterns provide the basis for predicting future water quality problems and the requirements for water quality management systems. Data have been collected from a variety of published and unpublished reports. Supplemental projections have been made where necessary. The several sources of data have presented some conflicting estimates and predictions, and in these situations judgment has been used to select representative numbers.

The need for additional water developments and the timing of their implementation is dependent upon the projected rate of growth of the economy. However, the estimates often vary considerably. For example, table 8 compares estimates of population and irrigated area growth as used in the California Region Framework Basic Plan (Base) and as developed by the Office of Business Economics and the Economic Research Service (OBERS). While both projections utilize the same region-wide population estimates, the Base projections anticipate a much greater growth for the Central Valley and the San Francisco Bay Basin that is expected by OBERS. The Framework Plan also projects a greater growth of irrigated agriculture in the Central Valley as well as the Region as a whole than does OBERS.

ECONOMIC PROJECTIONS

California has a distinctly urban population, with 86 percent of the people residing in cities. In the United States, 70 percent are city dwellers, and in the Central Valley 64 percent of the population is classed as urban.

Various studies indicate that the population of California and the Central Valley will continue, as in the past, to grow more rapidly than most of the rest of the Nation. The rate of growth will depend to a large extent on the economic opportunities afforded locally, in comparison with opportunities elsewhere in the United States.

Over the years there has been a notable development of industrial activity in the Central Valley area. Much of this increase is closely allied with agriculture, but population growth has also given rise to many service industries.

Table 9 presents projections of population, employment, per capita income and irrigated area for the Central Valley and the San Francisco Bay Basin as estimated in the California Region Framework Studies. In both areas employment in service industries and per capita income are expected to grow more rapidly than

Table 8. Comparisons of Population and Irrigated Area Projections
(Quantities in Thousands)

	Population		Net Irrigated Acreage	
	Base	OBERS	Base	OBERS
1980				
San Francisco Bay	5,697	5,211	122	109
Central Valley	3,722	3,726	7,680	7,292
California Region	25,465	25,465	9,904	9,362
2000				
San Francisco Bay	8,421	7,296	121	117
Central Valley	6,482	5,391	8,284	7,580
California Region	38,181	38,181	10,501	9,569
2020				
San Francisco Bay	11,225	9,870	120	114
Central Valley	12,038	7,582	8,834	8,057
California Region	54,941	54,941	11,044	9,880

Table 9. Projected Economic Parameters
Central Valley and San Francisco Bay
(Per Capita Income in dollars; other quantities in thousands)

	1960	1980	2000	2020
CENTRAL VALLEY				
Civilian Employment	830	1,407	2,544	4,826
Agriculture	130	126	123	120
Manufacturing	125	209	338	586
Services	575	1,072	2,083	4,120
Population	2,429	3,722	6,482	12,038
Per Capital Income	2,232	4,268	7,351	12,624
Irrigated Acreage	5,985	7,680	8,284	8,834
SAN FRANCISCO BAY				
Civilian Employment	1,371	2,339	3,483	4,646
Agriculture	31	25	22	18
Manufacturing	323	549	791	1,011
Services	1,017	1,765	2,670	3,617
Population	3,539	5,697	8,421	11,225
Per Capita Income	2,768	5,114	8,249	13,292
Irrigated Acreage	160	122	121	120

population; manufacturing employment should parallel population growth while direct employment in agriculture will continue to decline. The irrigated area is expected to increase by almost 50 percent in the Central Valley, but decline by 25 percent in the San Francisco Bay area by the year 2020. The population of the combined areas is projected to grow from the 1960 total of 6 million to over 23 million by 2020.

PROJECTED WATER DEMANDS

An estimate of the growth in demand for water in the Central Valley is illustrated on figure 3. The annual total gross surface water requirement for the valley estimated at about 12.1 million acre-feet in 1960 is expected to increase to 18 million acre-feet in 1980 and about 19 million acre-feet in 2000. The gross surface water requirement for export is expected to increase from 0.3 million acre-feet in 1960 to 3.8 million in 1980 and reach 5.2 million acre-feet by 2000. These estimates show demands for irrigation water growing sharply through the 20-year period 1980 to 2000. The expected municipal and industrial demands tend to increase more rapidly following 1970.

PROPOSED WATER RESOURCES DEVELOPMENTS

Schedule of Project Additions

Project additions have been planned to develop the total available supply indicated on figure 3. The projects (most of which are shown on figure 4) would be authorized by 1980, constructed by 1990 and project yield fully utilized by 2000.

Table 10 identifies the projects constructed, under construction, and proposed that would provide the total available surface supply shown on figure 3 and the present expectancy for completion.

Project features necessary for conveyance of surface water to places of use are identified on table 11. Table 12 presents the project features and expected growth in water export requirements from 1960 to 2000.

Schedule of Capital Investment

The capital outlay to accomplish the Federal construction program in keeping with projects identified on tables 10 to 12 is presented on table 13. Estimated cost through 1980 involves a predominance of storage or water development facilities occurring during the period 1960 to 1980. Beginning in the mid-1970's and until about 1990 the construction programs will be dominated with the construction of conveyance facilities.

CENTRAL VALLEY CALIFORNIA SURFACE WATER SUPPLY AND REQUIREMENTS WITH FEATURES

AUTHORIZED	BY	1980
CONSTRUCTED	BY	1990
UTILIZED	BY	2000

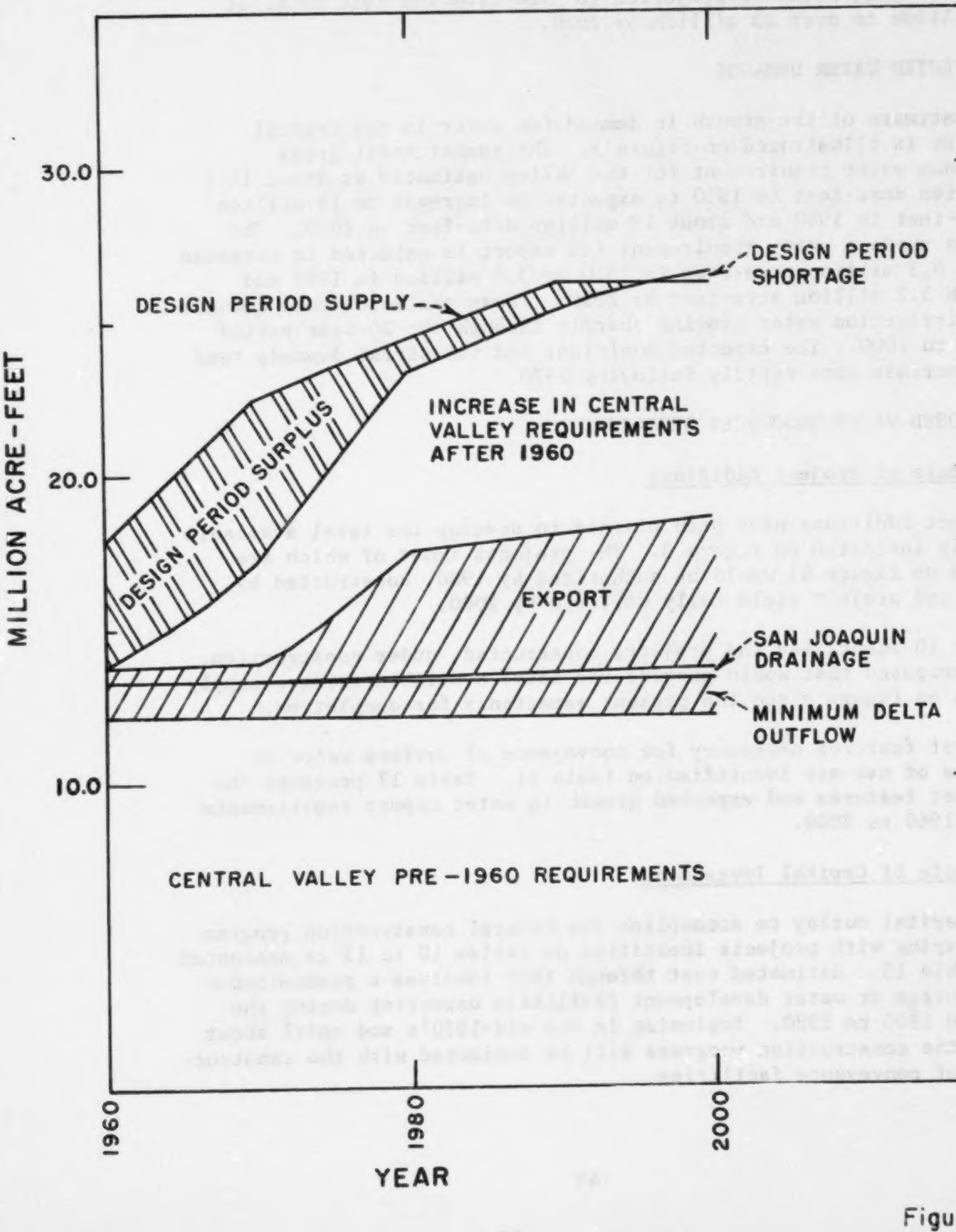


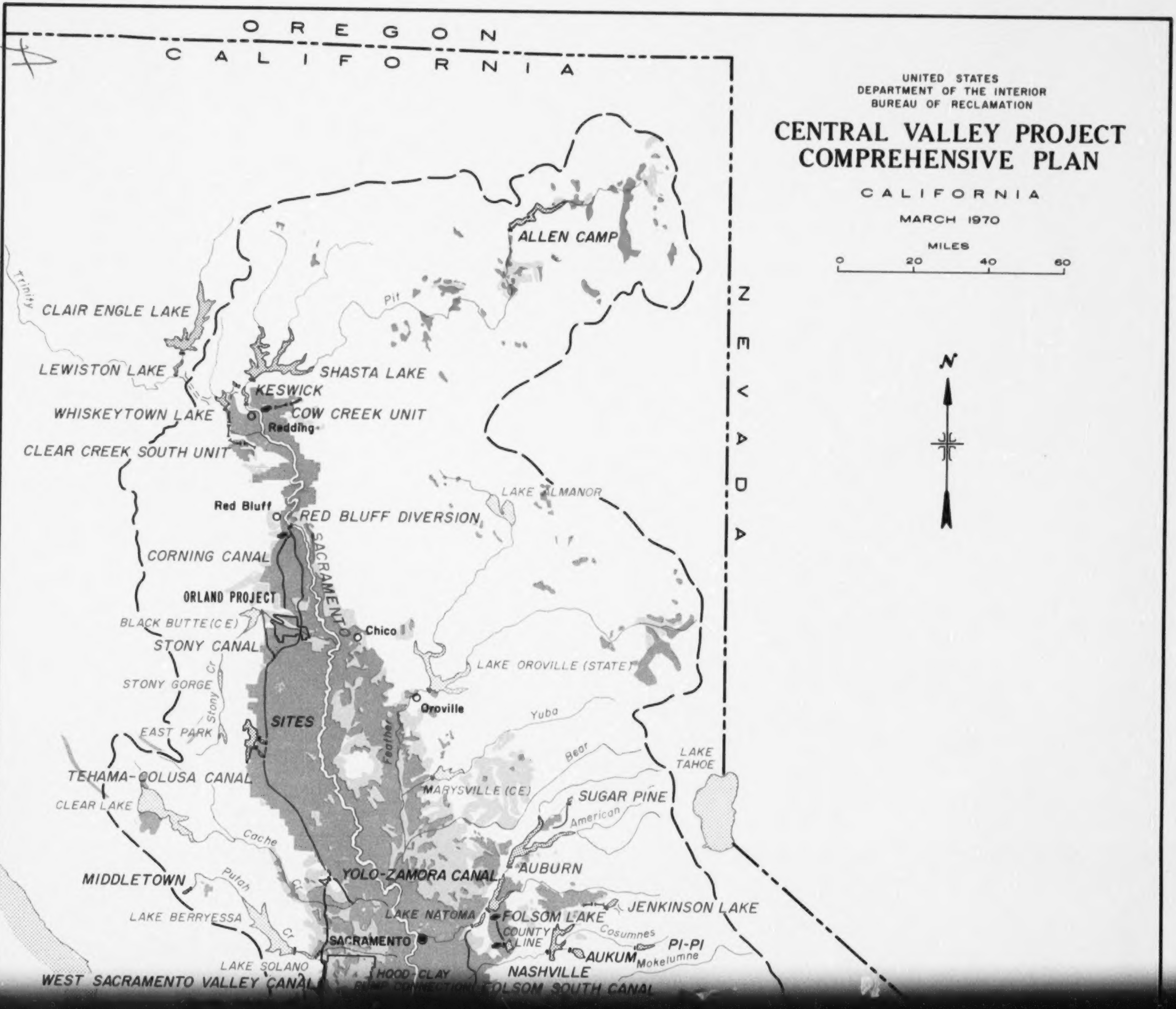
Figure 3

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

CENTRAL VALLEY PROJECT COMPREHENSIVE PLAN

CALIFORNIA

MARCH 1970


MILES
0
20
40
60
N
OREGON
CALIFORNIA
NEVADA
Trinity
CLAIR ENGLE LAKE
LEWISTON LAKE
WHISKEYTOWN LAKE
CLEAR CREEK SOUTH UNIT
SHASTA LAKE
KESWICK
COW CREEK UNIT
Redding
Pit
ALLEN CAMP
Red Bluff
RED BLUFF DIVERSION
LAKE ALMANOR
CORNING CANAL
SACRAMENTO
ORLAND PROJECT
BLACK BUTTE (CE)
STONY CANAL
Chico
LAKE OROVILLE (STATE)
STONY GORGE
Stony Cr
Oroville
Yuba
EAST PARK
SITES
Feather
Bear
LAKE TAHOE
TEHAMA-COLUSA CANAL
MARYSVILLE (CE)
SUGAR PINE
CLEAR LAKE
American
Cache
AUBURN
MIDDLETOWN
Putah
YOLO-ZAMORA CANAL
JENKINSON LAKE
LAKE BERRYESSA
Cr
LAKE NATOMA
FOLSOM LAKE
COUNTY LINE
Cosumnes
PI-PI
SACRAMENTO
AUKUM
Mokelumne
LAKE SOLANO
HOOD-CLAY PUMP CONNECTION
NASHVILLE
WEST SACRAMENTO VALLEY CANAL
FOLSOM SOUTH CANAL

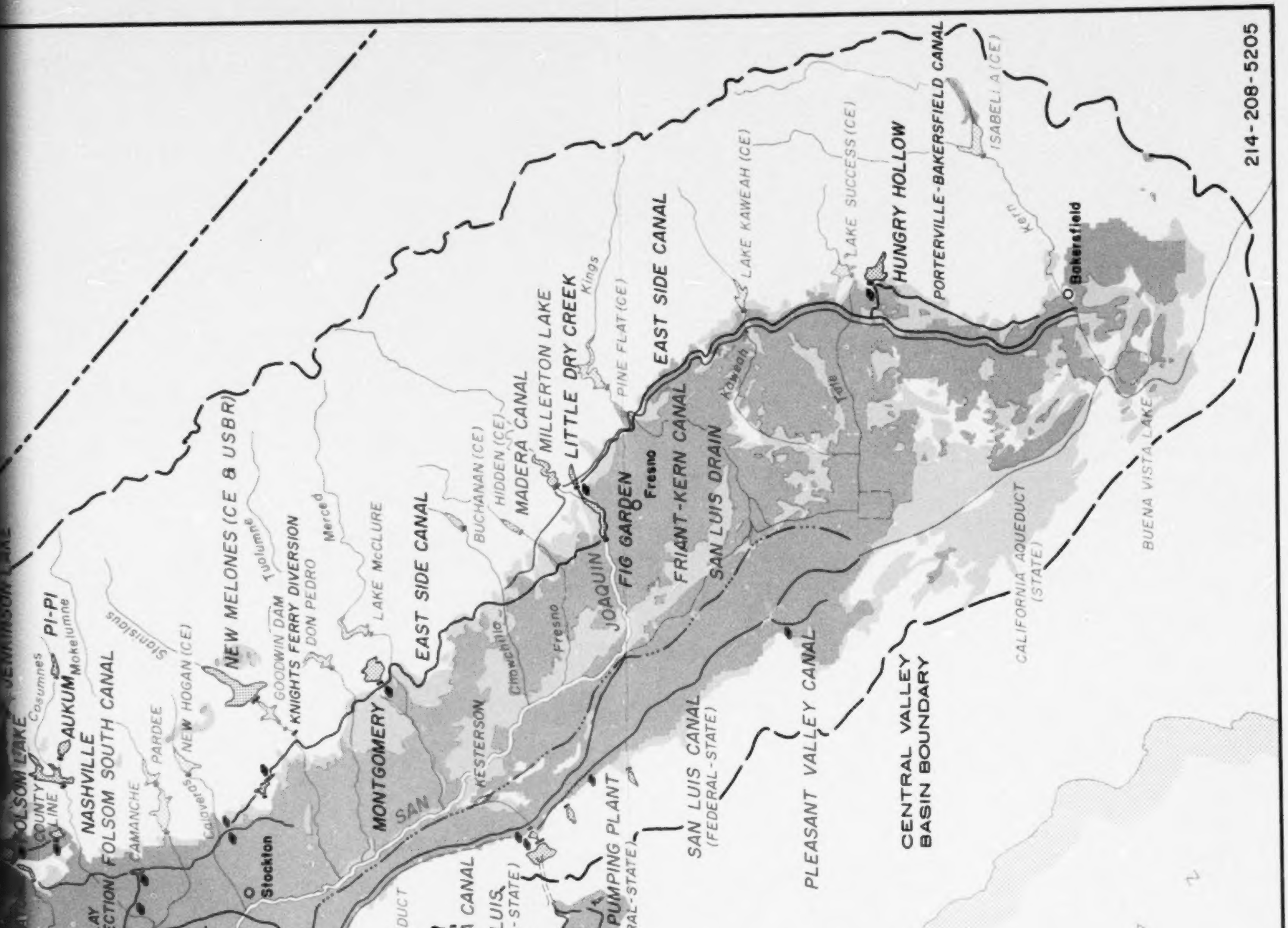

214-208-5205
LAKE BERRYESSA
WEST SACRAMENTO VALLEY CANAL
SOLANO PROJECT
LAKE SOLANO
PUTAH SOUTH CANAL
DELTA CROSS CHANNEL
PERIPHERAL CANAL
HOOD-CLAY PUMP CONNECTION
SACRAMENTO
CONTRA COSTA CANAL
KELLOGG
San Francisco
TRACY PUMPING PLANT
SOUTH BAY AQUEDUCT (STATE)
CALIFORNIA AQUEDUCT (STATE)
San Jose
DELTA-MENDOTA CANAL
SAN LUIS (FEDERAL-STATE)
SAN FELIPE DIVISION
Watsonville
DOS AMIGOS PUMPING PLANT (FEDERAL-STATE)
FOLSOM LAKE
COUNTY LINE
NASHVILLE
FOLSOM SOUTH CANAL
AUKUM
Cosumnes
Mokelumne
PI-PI
JENKINSON LAKE
CAMANCHE
PARDEE
Calaveras
NEW HOGAN (CE)
NEW MELONES (CE & USBR)
Stanislaus
GOODWIN DAM
KNIGHTS FERRY DIVERSION
DON PEDRO
Tuolumne
Merced
LAKE McCLURE
Stockton
MONTGOMERY
SAN JOAQUIN
KESTERSON
EAST SIDE CANAL
Chowchilla
Fresno
BUCHANAN (CE)
HIDDEN (CE)
MADERA CANAL
MILLERTON LAKE
LITTLE DRY CREEK
Kings
PINE FLAT (CE)
EAST SIDE CANAL
FIG GARDEN
Fresno
FRIANT-KERN CANAL
SAN LUIS DRAIN
SAN LUIS CANAL (FEDERAL-STATE)
PLEASANT VALLEY CANAL
CALIFORNIA AQUEDUCT (STATE)
Kaweah
Tule
LAKE KAWEAH (CE)
LAKE SUCCESS (CE)
HUNGRY HOLLOW
PORTERVILLE-BAKERSFIELD CANAL
ISABELLA (CE)
Kern
Bakersfield
BUENA VISTA LAKE
CENTRAL VALLEY BASIN BOUNDARY
PACIFIC OCEAN
B
▨ Constructed or under construction
▨ Authorized
▨ Proposed
▨ Irrigated land
▨ Irrigable land

FIGURE 4

Table 10. Development of Surface Supplies in Central Valley Authorized or Expected to be Authorized Before 1980

Constructed Before Year	Project	Agency	Annual Yield (million A/F)
1960	Existing Diversions	Local	12.4
	Minimum Delta Outflow	Federal/State	1.3
	East Bay M.U.D. (unused)	Local	0.2
	Federal (unused)	Federal	3.6
	San Francisco (unused)	Local	0.3
	Subtotal		17.8
1970	Trinity and Whiskeytown	Federal	0.8
	Black Butte	Federal	0.1
	Collins and Camp Far West	Local	0.1
	New Exchequer	Local	0.2
	San Luis (State portion)	State	1.2
	North & South Bay, Vallejo	State	0.3
	State Export	State	2.0
	New Hogan and Sly Park	Federal	0.1
	Feather River Water Users	State	0.3
	Accumulative Subtotal		22.9
1980	New Bullards Bar	Local	0.4
	Buchanan and Hidden	Federal	0.1
	New Melones	Federal	0.2
	East Side Canal	Federal	0.4
	Auburn	Federal	0.3
	West Sacramento Canal	Federal	0.2
	Marysville	Federal	0.1
	Accumulative Subtotal		24.6
1990	Cosumnes	Federal	0.2
	Middle Eel and English Ridge	State/ Federal	1.1[a]
	Paskenta-Newville	Federal	0.3
	Accumulative Total		26.2

---

[a] Middle Eel import to provide 0.9 million acre-feet annually during "design 7-year dry period." In normal years will provide 0.6 million acre-feet.

Table 11. Utilization of Surface Supply in Central Valley by Features Authorized or Expected to be Authorized Before 1980

Expected Utilization Before Year	Project	Agency	Annual Yield (million A/F)
1960	Existing Diversions	Local & Federal	12.1
1970	Black Butte	Federal	0.1
	Collins and Camp Far West	Local	0.1
	New Exchequer	Local	0.2
	San Luis (State)	State	1.1
	New Hogan and Sly Park	Federal	0.1
	Feather River Water Users	State	0.3
	Sacramento Water Users	Federal	0.5
	San Luis (Federal)	Federal	1.1
	Subtotal		15.6
1980	Peripheral Canal	Federal	[a]
	West Sacramento Canal	Federal	0.6
	New Bullards Bar	Local	0.4
	Tehama-Colusa Canal	Federal	0.3
	City of Sacramento	Federal	0.2
	Buchanan and Hidden	Federal	0.1
	Folsom South Canal	Federal	0.8
	Accumulative Subtotal		18.0
2000	New Melones	Federal	0.2
	East Side Canal	Federal	1.3
	Cosumnes	Federal	0.2
	Placer County - El Dorado	Local	0.1
	English Ridge	Federal	0.1
	Accumulative Total		19.9

---

[a] Facility contributes to quality and efficiency of service.

Table 12. Export from Central Valley by Features Authorized or Expected to be Authorized Before 1980

Export Before Year	Project	Agency	Annual Yield (million A/F)
1960	East Bay M.U.D. & San Francisco & Contra Costa Canal	Local & Federal	0.3
	Minimum Delta Outflow	Federal & State	1.3
	Subtotal		1.6
1980	North & South Bay Aqueduct	State	0.3
	California Aqueduct (Southern California)	State	2.0
	Contra Costa Canal	Federal	0.1
	Kellogg	Federal	0.2
	San Felipe	Federal	0.3
	East Bay M.U.D.	Local	0.2
	San Francisco	Local	0.3
	San Joaquin Valley Drainage	Federal	0.1[a]
	Accumulative Subtotal		5.1
2000	East Bay M.U.D.	Federal	0.3
	California Aqueduct (Southern California)	State	0.9
	San Joaquin Valley Drainage	State & Federal	0.2[a]
	Accumulative Total		6.5

---

[a] Water included in State and Federal San Luis Import.

Table 13. Central Valley, California Federal Projects Authorized or Expected to be Authorized Before 1980

Constructed After 1960 and Before Year	Project	Estimated Costs ($1,000,000)
1970	Trinity River Division	$ 225
	Black Butte	15
	San Luis Unit	698[a]
	New Hogan	15
	Sly Park	7
	Subtotal	960
1980	Peripheral Canal	209[b]
	Kellogg	70
	Buchanan Reservoir	16
	Hidden Reservoir	19
	New Melones Reservoir	145
	East Side Division	854
	Auburn-Folsom South	467
	West Sacramento Canal	225
	Marysville Reservoir	155
	Accumulative Subtotal	3,150
1990	Cosumnes	176
	English Ridge	219
	Paskenta-Newville	127
	Dos Rios	378
	Accumulative Total	$4,020

---

[a] Includes $188 million as State share of cost.

[b] Includes $101 million as State share of cost.

The cost estimates projected beyond the year 1980 are difficult to predict and may prove substantially greater because of rising construction costs.

ALTERNATIVE PRICING STRUCTURES

In the early 1960's, water rates (per acre-foot) charged by irrigation districts in the Central Valley ranged from $0.55 to $10.45 in the Sacramento Valley and $0.60 to $31.25 in the San Joaquin Valley, with median rates being about $1.60 and $6.30, respectively. The rates included distribution and drainage costs.

Ground-water pumping costs also varied greatly, depending primarily on amount of lift and annual delivery. In the Sacramento Valley the costs ranged from $2.50 to $16 per acre-foot, while in the San Joaquin Valley, where some lifts exceeded 600 feet, costs ranged from $3 to $30.

A representative sample of six cities dispersed throughout the Central Valley showed that the cost of water delivered to urban users ranged from $18 to $49 per acre-foot, with five of the cities under $35.

The effect of escalating water prices upon use has over the years been the theme of much speculative consideration. In the main, generalizations on the topic have concluded that municipal water users can pay almost any price for water, that most industries find cost of water a small factor in their processes, that heavy water use industries might tend to relocate, and that irrigated agriculture would be subdued by a marked increase in cost. Based upon assumed environments and constraints, these conclusions were deemed logically drawn.

Application of this form of generalization and resulting conclusions to the Central Valley does not appear prudent. Water is available at the present time and for the foreseeable future for all purposes in the Central Valley at what would appear to be reasonable water rates. In the case of irrigation use, the large expanses of excellent soil, the long growing season, the management experience and finance availability, the expertise in scientific agricultural production, and the extensively developed marketing system present a unique environment in which the cost of water for irrigated agriculture is not controlling.

Extensive development of irrigated agriculture has taken place and is expected to continue to expand through the use of ground waters. Surface water development that may be undertaken in the future will not be involved with the development of new lands, but will provide, in varying degrees, supplemental water for a then existing, developed, irrigated agricultural community. The development will require high costs for water.

The matter of water price in supplying supplemental water will in each case, of necessity, be weighed against the partial reduction of the efficiency of an existing irrigated agricultural enterprise rather than against suspension of operation. A water pricing policy that would not sustain the existing agriculture development would have to face the political-economic question of withdrawing a block of irrigated agricultural production from the national economy. The California-Central Valley environment does not at this time or in the foreseeable future appear to offer much basis for such drastic consideration.

In extremes where sufficient water was not available or where the growing season or the soils and the markets also were not favorable, these decisions might be desirable. The outlook for California with the expected population increases and the demands of the environment and agricultural productivity of the Central Valley make such speculations academic. The municipal, industrial and agricultural water users are able to pay substantial sums for their water service.

To match possible escalating costs of water of the future is a projected parallel rise in personal income and industrial and agricultural commodity prices. In addition, increased efficiency in water use and increased productivity with technological advances of the future should at least maintain the favorable balances which would permit water users in agricultural as well as industrial sectors to continue to meet rising water costs to support such increased supplemental needs as may become necessary.

This qualitative discussion has refrained from presenting quantitative expressions of some near-marginal operations that unquestionably exist in a large area such as the Central Valley. With time, the poorer lands and the inefficient operations will be replaced by efficient operation on the better lands. These processes continue in spite of water costs and are far more significant than escalations in water prices that can be foreseen as being associated with the extensive water resources development plans that have been developed in California.

DEVELOPMENT IMPACT ON WATER QUALITY

The continued development of flood control systems, water conservation storage, and water diversion, transportation and distribution facilities in the Central Valley will be necessary if projected economic development is to take place. The expected consequences of water resource projects include increases in social benefits as the resulting project benefits offset identified project detriments. Most water resource developments will have a mixture of beneficial and detrimental consequences, and the usual project justification indicates that benefits exceed project costs plus costs of mitigating identified adverse effects. This approach may be justifiable for an individual project, but a project-by-project approach may understate or fail to recognize all of the benefits and detriments throughout its area of influence.

In the following discussion the assumption has generally been made that projected economic development will occur without limitation by water quality. Also, proposed projects have been considered en masse as being available to meet future needs. Both assumptions are consistent with the restraints upon this study but will require reexamination in future investigations.

A Classification of Water Quality and Quantity Consequences

A brief summary of major consequences of proposed development follows as a prelude to more detailed discussion later. The consequences of development may initially be classified into two general groups, (a) more intensive water use and (b) alterations in natural hydrology.

Water conservation projects will typically support development of more intensive water use or reuse with subsequent increases in benefits from consumptive use and detriments from waste production. This situation is typical of water supplied to municipal, industrial or agricultural water users. Specific examples of the water quality impacts resulting from development include:

1) Increasing use and reuse of irrigation water will ultimately result in a return flow that is not suitable for most beneficial uses. An example is the drainage water from developments along the west side of the San Joaquin Valley. This return water is predicted to have undesirably high concentrations of minerals and biostimulants such as nitrogen. Because of the nature of this return water, it must be transported away from the farm areas in order for agriculture to continue successfully. This collected return water should be renovated and discharged in a location where ecological damages would be minimized.

2) Discharge of large quantities of municipal and industrial waste water within a limited geographical area can result in seriously polluted surface waters (or ground waters) where water uses are restricted and fishery or recreation values are reduced.

3) Economic development, involving changes in type or intensity of land use, will always impact hydrology and water quality at least locally. Waste treatment alone cannot eliminate this impact. Some effects can be minimized by proper planning and development practices.

4) Extensive recreation use of multiple-purpose reservoirs, upland areas and along streams can lead to problems of bacterial contamination and eutrophication. There is an increasing need for adequate and well maintained sanitation facilities at recreation sites and adequate treatment or protection of the water supply. Recreational subdivisions need to have sewerage for the entire development and provide an appropriate degree of treatment or land disposal of wastes.

Water resource development facilities such as impoundments, diversions and drainage facilities will alter stream hydrology, as will changes in land use and land management practices. Seasonal redistribution of flows has potential for both the intensification of water quality problems or the relief of problems aggravated by earlier development.

Some potential examples of hydrologic impact related to the Central Valley are:

1) Seawater incursion in the Sacramento-San Joaquin Delta is dependent upon the magnitude and duration of lower outflow. The present water quality and hydrology is a function of a regulated system of water releases and is not natural, being higher quality than during some historical periods.

2) Streamflow regulation and conservation may distribute the captured water into a pattern of seasonal flows which could be beneficial or detrimental to a fishery resource such as salmon and striped bass. Streamflow regulation to enchance salmon spawning is practiced, in addition to hatchery production, in the Central Valley. Although spawning runs to certain tributary streams have virtually been eliminated, projects on the Sacramento and American Rivers and elsewhere in the Sacramento Valley have improved the runs.

3) Decreasing streamflows by reducing capacity to assimilate and transport wastes can compound waste disposal problems. An example is the San Joaquin River near Stockton where large municipal and industrial waste discharge, minimal river flows due to upstream diversions and consumptive use and deepening of the channel cause low dissolved oxygen concentrations during the late summer and fall season.

4) Streamflow regulation affecting water quality and quantity characteristics can result in ecological changes in the stream itself and possible changes in the flora and fauna of adjacent lands.

5) Numerous factors cause an increase in stream temperatures. The most important of these is a reduction in stream flow. Other causes include various schemes of reservoir operation and the discharge of heated waters. The major impacts of increasing the temperature of streams are the delay of anadromous fish migration and the increased mortality of anadromous as well as resident fishes. Other effects are excessive algal growth and decreases in dissolved oxygen.

The water temperature below reservoirs can be influenced, however, by altering reservoir release schedules and providing facilities for selectively withdrawing water from different levels. Thermal pollution problems resulting from heated water discharges can be controlled by appropriate operation.

Future Water Quality Problems

North Coastal or Other Sources of Imported Water. The projected demand for additional water supplies for the Central Valley and South California can be met in a variety of ways. Current proposals envisage extensive development of the rivers of the north coast as the major source. Concern has been expressed over the impact of such development upon the environment and potential growth of the area. Controversy over the Corps of Engineers' proposed high Dos Rios Dam on the Eel River led the Governor to direct further studies of alternatives. It may be anticipated that all proposals for water resource development for whatever purpose will be subjected to the closest scrutiny for environmental impact.

A few of the more significant factors deserve mention. The anadromous fishery, salmon and steelhead, existing in all rivers and streams contributed significantly to both the economy and the amenities of the area. Preservation of the unique redwood forests of the region is an issue of popular concern of which water resource planners must be cognizant. Timber harvesting, road building and other land management practices have created problems of erosion, siltation, and turbidity in some basins. Problems of eutrophication have been identified and could be intensified by further development.

Sacramento Basin. Projected increase in the economy will lead to increased water use and reuse together with greater waste production. Proposed water development projects are primarily for flood control, water conservation and distribution. The available in-basin water supply will be supplemented by imports from other basins, while additional imported water will pass through the basin prior to use to the south.

The combined project effect on the anadromous fishery, which includes salmon, striped bass and American shad, will be a mixture of benefits and detriments. Blocked access to spawning areas can be compensated for by fish hatcheries and/or artificial spawning areas. Loss of downstream migrating immature fish into project diversions is expected to be controlled. Stable regulated stream flow and maintenance of high water quality in certain stream should be beneficial to the anadromous fishery. The new reservoirs provide additional fishing areas, which may compensate for any losses in the anadromous fishery or resident stream fishery.

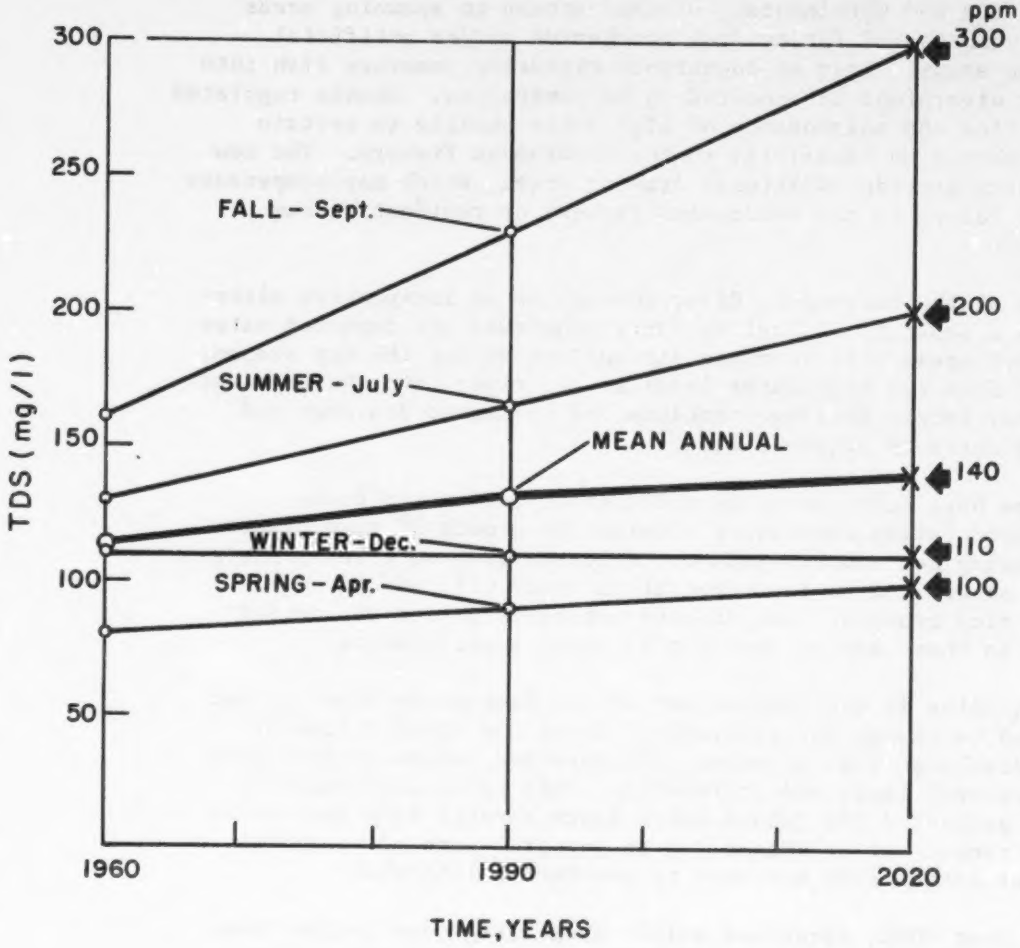
The use of the Sacramento River channel as an inexpensive alternate to a separate channel to carry conserved and imported water to export areas will increase streamflows during the dry season. Seepage from the high water level in the river into the adjacent lands may impose drainage problems and increased drainage and pumping costs on adjacent land.

Problems have been caused by releases of cold water from Sacramento Valley reservoirs slowing the growth of rice plants even during hot summer weather. Releases from multilevel outlets can be controlled so low temperature water will not adversely affect rice growers. But fishery interests prefer the colder water, so there may be conflict of water quality needs.

Water quality in the "main-stem" of the Sacramento River is not expected to change substantially. While the total volume of waste discharge will increase, the relative volume of transport water is very large and increasing. This relatively small impact projected for future waste loads results from the use of the Sacramento River channel as an integral part of the water transfer system from northern to southern California.

By the year 2020, dissolved solids from irrigation return flow will nearly double. A fivefold increase from domestic sources and a threefold increase from industrial operations are projected but these two sources are minor compared to drainage from irrigated land. Figure 5 illustrates the magnitude of seasonal variations in water quality anticipated in the lower Sacramento River. This figure is from the State San Francisco Bay-Delta Water Quality Control Program; however, the mean values are comparable to those projected in this study considering additional planned development. This predicted increase in TDS may have no particular water quality significance within the Sacramento River Basin as the values are well below the usual salt tolerance thresholds of most beneficial uses; however, the additional dissolved solids will have some significance after export to other areas for consumptive use. The larger than average imports to the Delta during dry years will tend to minimize quality variation historically associated with drought conditions.

PROJECTED TDS CONCENTRATIONS, SACRAMENTO RIVER AT FREEPORT



SOURCE: FINAL REPORT, TASK II-5
STATE S.F. BAY-DELTA WATER QUALITY
CONTROL PROGRAM

Figure 5

The optimistic projections of future quality in the Sacramento River do not necessarily apply to all tributary streams. A current example of a potential water quality problem which may be resolved through flow maintenance is the lower American River. In the Sacramento metropolitan area continued high water quality and adequate flows in the American River are desired for recreational purposes and fishery maintenance. The Auburn-Folsom South Canal Project will eventually divert up to 810,000 acre-feet annually of American River water either from the lower river at Lake Natomas, or from the Delta. Water released into the American River and then diverted from the Delta could first serve flow maintenance purposes in the American River in addition to its later consumptive use elsewhere at only slight increase in conveyance costs. The lower American River problem is compounded by the increasing urbanization of areas northeast of Sacramento. Flow requirements would increase in the absence of a regional sewerage plan for exporting wastes from the basin.

Nutrient loadings throughout the basin will continue to increase significantly. Clear Lake is an example of a water body suffering from advanced eutrophication aggravated by man's activities. There is reason to believe that more instances of localized overfertilization of lakes and streams will occur in the future. Land development around reservoirs must include sewerage and adequate treatment and disposal and land treatment measures for erosion control.

Since ground-water quality in the Sacramento River Valley is relatively good and water is generally abundant, the potential of rapidly decreasing ground-water quality is not as great here as in the San Joaquin and Tulare Basins.

San Joaquin Basin. Future water quality problems in the basin will be the result of wastes produced by a rapidly growing urban population, increased industrial activity, and increases in irrigated agriculture. Wastes from recreational activities can be expected to cause some localized quality problems in the mountainous headwater areas.

Domestic waste production will increase almost eightfold by 2020 and industrial waste production is estimated to almost triple. Present practices would indicate that a considerable waste load would reach surface streams, especially during the canning season. The nutrient load remaining after secondary treatment together with contributions from irrigation returns will be of such magnitude as to cause excessive enrichment of the lower San Joaquin River at low flows. Without some control of both minimum streamflow and the waste effluents, dissolved oxygen problems can be expected due to the oxygen demand from respiring aquatic plants, organic wastes, nitrification, and the demand from decaying algal biomass within the streams.

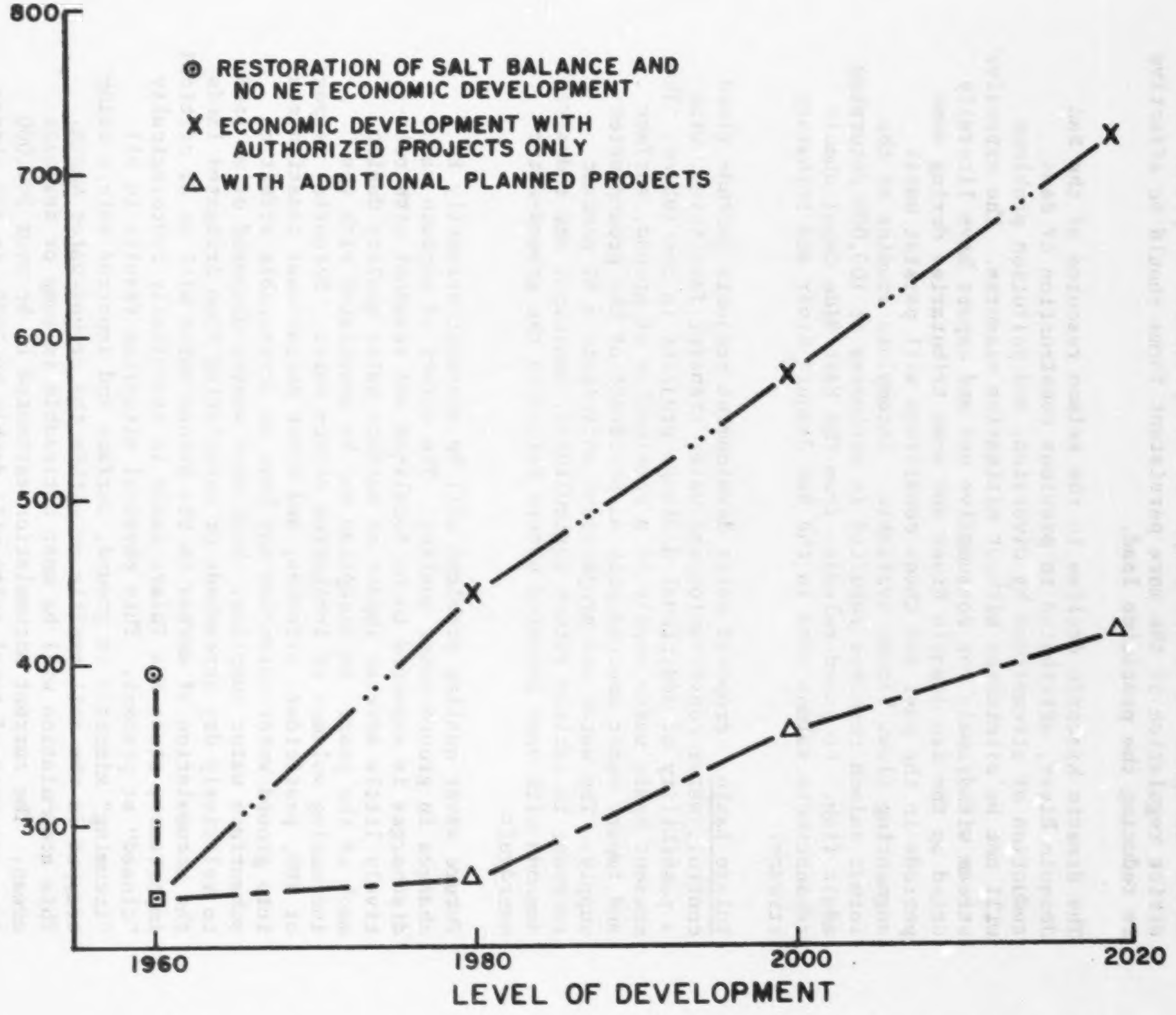
A problem of high total dissolved solids, salinity, etc., will continue to exist in the lower San Joaquin River and ground water in the basin. Without corrective measures, reduction in water quality, both surface and ground water will adversely affect agricultural users and other beneficial uses in the valley trough and the Delta. The causes and cures for this deterioration are complex and multiple. Unless corrective measures are taken, increasing the imported water supply, irrigated acreage and consumptive use will further aggravate the water quality problems, as greater quantities of poor quality return flows must be handled in future years. The affected agricultural users will be faced with suffering the consequences of poor water quality--reduced crop yields and less farm income. To maintain crop yield despite declining water quality, extensive areas of subsurface drainage will be installed.

Recent evaluation of the sources and fate of dissolved solids within the basin indicates that the valley has been functioning since at least 1959 as a "salt trap", with perhaps 40 percent per year of the dissolved solids entering the system not appearing in surface outflow. A return to a salt balance will also greatly increase salt transport requirements.

Figure 6 illustrates the projected changes in annual mean total dissolved solids concentration in the San Joaquin River at Vernalis. The impact of the projected rate of irrigation development without any additional major water importations or water quality control measures is such as to increase mean concentration 50 percent beyond the water quality standard at Vernalis. Also shown is the effect of the same rate of economic development with additional planned water resources developments, including currently proposed operation to mitigate adverse effects and enhance beneficial uses. Mean concentration would increase in 2020 to approximately the concentration which would occur at present if a salt balance existed.

Under a dry year streamflow and water delivery schedule some of these water qualities are expected to be lowered significantly and constitute a more critical water quality situation. Fishery flows from the East Side Canal would tend to minimize variation in water quality.

Waste production from a fourfold increase in recreational activities is expected to result in localized problems in the mountainous areas. Resultant problems from recreational waste production will tend to be bacteriological and eutrophic in nature.



PREDICTED ANNUAL MEAN TOTAL DISSOLVED SOLIDS CONCENTRATION
SAN JOAQUIN RIVER AT VERNALIS

Figure 6

It is anticipated that current efforts to restrict use of chlorinated hydrocarbon compounds will stimulate the development and use of other types of pest control measures. Increased effort designed to insure proper use of pesticide compounds and strict regulation of the more persistent forms should be effective in reducing the pesticide load.

The drastic historic decline in the salmon resource of the San Joaquin River, attributed to previous construction of dams, reduction of streamflows by diversion, and pollution problems will not be eliminated without mitigation measures. The extensive stream withdrawals for consumptive use and export have literally dried up the San Joaquin River and some tributaries during some periods in the past and these conditions will persist until augmenting flows become available. Incomplete studies of the former salmon resource resulted in estimates of 100,000 returning adult fish. Proposed releases from the East Side Canal should reconstitute salmon runs in the San Joaquin River and tributary streams.

Tulare Basin. Proposed water development projects include flood control, water conservation and water transfer facilities, with a possibility of additional drainage projects in the future. The present basin water supply is a combination of ground, surface and import water sources with an overdraft of the ground-water supply. The water use projections anticipate a 67 percent increase to satisfy future agricultural, municipal and industrial demands with some imported waters relieving the ground-water overdraft.

Future water quality problems will be apparent primarily in changes in ground-water quality. The effect of surface waste discharges is expected to be localized and seasonal with relatively little adverse impact on surface water quality during much of the year. An exception may be associated with the increasing volumes of irrigation return water. Potential seepage of TDS, pesticides, nitrates, and other pollutional constituents into ground-water resources may have an irreparable effect on subsurface water supplies. With most wastes disposed of on land, to relatively dry streambeds or percolating from irrigated lands, the accumulation of wastes in the ground water will be of critical importance, since the Tulare Basin is essentially hydrologically "closed" at present. This physical situation results in all "incoming" minerals in ground, surface and imported waters being trapped in the soil profile or within the ground-water basin. This accumulation will be most noticeable in sump or drainage areas. The current accumulation estimated to be over 500,000 tons per year of total salts will double by 2020, in the absence of additional export drainage facilities to supplement those provided the San Luis service area. This accumulation of salt is estimated to increase the average concentration in the ground water within 200 feet of the ground surface by 250 mg./l. by 2020, based upon present rate of accumulation.

The water users most affected would be those who withdraw water from the "sump" or ground-water trough areas. These water users include municipalities as well as agricultural interests, so the impact will be general. The water quality problems described under present conditions would be aggravated in the future with municipal supplies being particularly hard hit because of the nitrate problem.

Sacramento-San Joaquin Delta and San Francisco Bay. Water quality in the Delta and, to some extent, the Bay is unique in its direct dependence upon quantity and quality of flow from all other basins within the Central Valley and diversions for export southward. The Delta receives flow from the Sierra and from the Sacramento and San Joaquin Basins, including much of the municipal, industrial and agricultural wastes of those basins. Treated drainage from the San Luis Unit and perhaps other parts of the Tulare Basin may be added. Exports from the Delta may be diverted from the Sacramento River near Hood into the proposed East Side Canal and Peripheral Canal which would hydraulically be isolated from other channels in the Delta. Maintenance of acceptable water quality in the Delta in the future is dependent upon successful implementation of means to control sea water incursion, water quality management in the basins tributary to the Delta and control of wastes discharged directly to the Delta water courses. Quality in south and central San Francisco Bay will be more directly dependent upon local or regional municipal and industrial waste treatment and disposal practices. Quality in Suisun and San Pablo Bays is dependent on a combination of these factors.

Domestic waste production within the Delta-Central Sierra Basin is projected to increase over 5 times by 2020, industrial waste production 2½ times, and recreational wastes by almost 6 times. Drainage from irrigated lands within the basin is projected to contribute about 40 percent more dissolved solids by 2020.

Domestic waste production within the San Francisco Bay Basin is projected to increase nearly 3 times by 2020, industrial waste production 1½ times, and recreational wastes by 3 times. The discharge of nutrients from domestic sources is projected to be more than double its present value. Overall recreation usage has been projected to increase sevenfold by 2020 with water-contact sport usage increasing accordingly, if water quality is adequate.

Thermal wastes are becoming an increasing problem with the advent of fossil and nuclear power plants, each requiring about 2,000 cubic feet per second of cooling water per 1,000 megawatts of capacity. The present diversion of 4,000 c.f.s. may be increased to 16,000 c.f.s. by the addition of proposed nuclear power development in the Bay-Delta area. The potential effects of increased water temperature is expected to be detrimental to anadromous fish and their food sources.

Since the Delta is the hydrologic "key" to the Central Valley, it is not surprising that virtually all proposed water resource projects discussed in this report are capable of a profound impact upon its water quality. Waters released from storage or otherwise diverted to the Sacramento River for export southward are, and will continue to be, recaptured in the Delta, together with any available uncommitted waters. Without water developments additional to those indicated under Proposed Water Resources Developments, median annual outflows from the Central Valley to the Bay will be less than a quarter of 1960 flows if the projected 2020 level of economic development is reached. The Delta also is the passageway for salts and refractory wastes from 40 percent of California to ultimate disposal in the ocean. The benefit tradeoff is this - increasing water delivery to and development in the Central Valley and export areas means more future agricultural, industrial, and municipal water supply benefits. But development supplying these potential water users could mean diminishing the water supply and other benefits available to some present users, which may create detriments. Care should be taken that waste waters created by the new uses do not compound the detriments.

To a large degree the water quality problems that will require solution in the coming years are evident now. Present problems, however, are minor compared with the conditions that might develop in the next few years if present wastewater management practices are perpetuated. Based on the findings of the State San Francisco Bay-Delta Study, ". . .the Bay-Delta system has no additional assimilative capacity for wastes above the quantities now being discharged. Eutrophication of the system, particularly in the Delta and South Bay, is well advanced. Increasing waste loads and decreasing availability of "flushing" water from the Sacramento and San Joaquin Rivers will inevitably accelerate the aging or eutrophication of the system.

"Dissolved oxygen problems from biochemical oxygen demand in wastes can be eliminated or controlled by proper design of waste treatment plants using technology which is available. The problem of controlling algal growth and its effects on dissolved oxygen is less well understood, but is of equal or greater importance.

"The effects of toxic wastewater discharges on the animals living in the Bay sediments can be observed now, and these effects will increase as the amounts of wastes discharged to the system increase. It can also be expected that the continued addition of toxicants to the system will result in a detectable, deleterious effect on the higher forms of aquatic life.

"Water quality problems near the heavily industrialized areas of San Pablo and Suisun Bays have not been obvious in the past because of the large amounts of water released from the Delta. As these flows are decreased in the future, nutrients and toxic materials will increase in concentration and will accumulate in the waters and sediments with consequences which, although not precisely predictable at the present time, cannot be anything but adverse."

Projection of future changes in water quality in the Delta and Bay is dependent almost entirely upon assumptions as to the construction and operation of future water resource projects and regional waste management systems. Projections might range from water quality conditions little different from those at present to degradation of such magnitude as to eliminate much of the present beneficial use made of these waters. There appears to be little point in presenting in detail various predictions since the question of future water quality will be resolved outside the technical arena. Major elements of any solution would appear to include incorporation into the State-Federal water quality standards of provisions to protect striped bass spawning and water supply in the western (seaward) Delta, adoption of an effective plan of implementation, and eliciting firm commitments from private water users as well as appropriate local, State and Federal agencies.

Unless great improvements are made in nutrient removals from municipal, industrial and agricultural wastes tributary to the Delta and Bay, algal growths will seriously influence beneficial uses throughout the area. One consequence will be a need for greatly increased per capita waste handling costs.

V. WATER QUALITY MANAGEMENT SYSTEMS

The continued development of the Central Valley and of southern California will require water supplies beyond the capabilities of presently constructed or authorized projects. The mixture of major local, State and Federal projects presently proposed has been presented previously, together with a schedule of development consistent with projected increase in demand. Water quality problems both present and potential, have also been considered. Some possible deleterious effects of development, their ecological consequences, and methods of mitigation are summarized in table 14 for reference in discussing specific environmental quality control techniques.

The estimated waste loads and predicted water quality effects are one part of an environmental quality control system design. A second, and very important part of this system design, is the consideration of alternative control methods which can satisfy water quality standards or other design objectives. Another typical part of a system design is the benefit description, but this component may also be implicitly contained in the water quality standards. The system design problem is to choose the optimal control system as a function of waste loads, alternative control methods and benefits or water quality criteria. Performing this conceptual optimal waste control system design for the study area is an expensive and time consuming undertaking, and no one has yet attempted to design a comprehensive system. However, there have been studies of possible components of this system and so some information is available.

This discussion will present a summary of available studies on waste handling systems for different parts of the Central Valley and adjacent areas together with consideration of possible additions to or omissions from presently planned water resource development facilities. The summation of the various components might be considered as a conceptual basis from which a comprehensive regional plan for environmental control could evolve; however, it cannot necessarily itself be considered an optimal regional plan. The total costs for water quality control associated with the various component projects might be reduced for a more optimal plan. But total cost might also increase for a more comprehensive plan since only several major water quality management requirements have been considered here.

The State-Federal water quality standards comprise most of the basis for system design. Inasmuch as the water quality standards have been derived through the public hearing process and accepted by the State and by the Secretary for the Federal Government, they

Table 14. Some Possible Deleterious Effects of Development, Their Ecological Consequences, and Methods of Mitigation

Type of Development and Possible Deleterious Effects	(C) Possible Ecological Consequences, and (M) Methods of Mitigation
Economic Development	
(1) Waste flow increases in amount and complexity	(C) Potential pollution problems increase locally and regionally. (M) Reclaim wastes, treat and export to approved disposal areas.
(2) Minimum natural streamflow diminishes	(C) Capacity to assimilate waste flows diminishes; instream beneficial uses impaired. (M) Release reservoir inflow or stored water.
(3) Ground-water overdraft	(C) Ground water quality problems; land subsidence. (M) Import water to meet demands and/or increase recharge.
(4) Heated waste water	(C) Increased stream temperatures. (M) Pond waste water and/or blend with cold water released from reservoir, cooling towers.
Waste Handling System	
(1) Transport wastes to areas of insufficient assimilative capacity	(C) Ecological impact at point of discharge (M) Improve treatment, transport wastes to suitable area.

Table 14 (Cont.) Page 2 of 3

Type of Development and Possible Deleterious Effects	(C) Possible Ecological Consequences, and (M) Methods of Mitigation
Waste Handling System (Cont.)	
(2) Concentration of wastes in point discharge	(C) Localized degradation. (M) Improve treatment, alter and/or increase points of discharge.
Reservoirs	
(1) Eutrophication of impounded water	(C) Excessive algal growth; dissolved oxygen deficiencies. (M) Selective level outlets, reservoir management improve watershed waste handling practices.
(2) Elimination of flood flow	(C) Eliminate desirable ecologic effects of occasional flooding; sediment deposition in channels. (M) Provide flushing flows, control erosion.
(3) Block fishery access to spawning areas	(C) Reduce anadromous fishery potential. (M) Build hatcheries and/or new spawning areas, choice of facility design and location, ladders.
(4) Inundate recreation, agricultural, or cultural interest areas	(C) Sometimes difficult to evaluate quantitatively. (M) Develop substitute areas, choice of facility design and location.
(5) Increased recreation contamination opportunity	(C) Bacterial and eutrophication considerations. (M) Improve policing and define type and area of recreation, provide waste handling system.

Table 14 (Cont.)

Page 3 of 3

Type of Development and Possible Deleterious Effects	(C) Possible Ecological Consequences, and (M) Methods of Mitigation
Reservoirs (Cont.)	
(6) Minimum flows downstream diminished	(C) Instream beneficial use impaired. (M) Release reservoir inflow or stored water.
(7) Effect on downstream turbidity and dissolved oxygen	(C) Influences flora and fauna, and beneficial withdrawal and inplace users in various ways. (M) Watershed management, selective outlet releases, improved outlet valve design.
(8) Thermal stratification	(C) Adverse downstream temperature. (M) Control by selective outlet release, reservoir mixing.
Water Transport System	
(1) Raise adjacent water table	(C) Drainage problems; soil structural changes. (M) Install drains, coordinate surface and ground water use.
(2) Reduce natural streamflow	(C) Complex effect on water quality and instream use. (M) No reduction below beneficial need, provide increased flow to other streams.
(3) Trap fish in system	(C) Fishery damage. (M) Install fish screens, stock fish in system.
(4) Import water incompatible with soils	(C) Soil structural changes. (M) Sample soil and water chemistry beforehand, provide needed additives, water quality management of supply and drainage.

are an objective expression of the public desire for a quality of water considered adequate to support the contemplated water uses. They may also be considered as a commitment by the State and Federal Governments to incorporate in Federal and State development and management of water resources, the necessary water quality control measures. Alternative sets of water quality criteria were not considered here. The controlling water quality criteria for the design proposed by the Bay-Delta Program are not at present a part of the water quality standards.

Implicit in the discussions below of various water quality management systems is the necessity for concerted regional action to resolve the regional problem. Throughout the study area appropriate large-scale single or multi-purpose agencies empowered to design, construct and operate the required facilities or contract for required services are almost universally nonexistent. Difficulties have been experienced for example in creating such an agency for the sewerage of the San Francisco Bay area, and the agricultural interests in the San Joaquin Valley appear no more willing to undertake joint action to implement drainage schemes. A notable exception is the recently created Delta Water Agency, empowered to develop and implement a water quality management plan for the Delta. Development of technical solutions for water quality management problems appears to be more advanced than the present ability to make institutional and financial arrangements to implement the solutions.

MANAGEMENT ASPECTS OF RESERVOIR AND CONVEYANCE SYSTEMS

These developments are mostly multi-purpose; however, greatest interest here is focused on those that provide flood control and water conservation to develop water supplies for use in the Central Valley or for export from it. Reservoirs located outside the valley will differ from those located in it only in the sense that their influence will be divided between their local basin and the Central Valley. In total, their effect will be similar. Perhaps the most important distinction between reservoirs is concerned with whether flow is diverted from the stream or merely redistributed seasonally using the stream's natural channel. In either case, there is a continuing necessity for inclusion of water quality management considerations in the design and operation of each reservoir, and diversion of a significant portion of the natural flow restricts planning flexibility, particularly immediately downstream from the reservoir. Recent water resources developments have been designed and operated to enhance water quality.

Changes in hydrology and water use can be examined for their effect on the anadromous fishery, general ecology, water pollution and recreational use of the streams.

Possible detrimental water quality/quantity related consequences of projects and possible methods of mitigation include:

1) A potential effect on the fishery and recreational resource would be a reduction in spawning area because of stream blockage, siltation of gravel spawning beds from reduction of periodic scouring flows and, possibly, increases in turbidity. Reservoirs capturing turbid flows normally passing to the sea during the high runoff period may remain turbid for prolonged periods and may result in unseasonal increase in stream turbidity, as inorganic and organic colloidal matter in these waters tends to settle out only very slowly. Prolonged maintenance of reduced flows, perhaps at elevated temperatures, will promote growth of vegetation in the stream channels further enhancing siltation as well as formation of nuisance algal growths. Reservoir operation permitting periodic scouring flows would help preserve the stream channel and preserve the productivity of spawning gravels. Better land management can potentially reduce the magnitude of the problem of turbidity and siltation.

   One beneficial effect of more stable streamflow is a reduction in the possibility that extremely low or high flows would destroy the eggs or immature fish. Flow fluctuations such as might be encountered below a power peaking facility (without reregulation) would be undesirable. Allowable maximum rate of change of flow should be specified as part of the reservoir operation rules with particular attention given to critical seasons.

   Maintenance of an anadromous fishery may require construction of hatcheries or artificial spawning channels. Realization of fishery benefits and recreational use of the impoundment is dependent upon creation and maintenance of a satisfactory environment.

   Water temperature in the reservoir and immediately downstream can be controlled by selective releases using a multi-level outlet facility. Water temperatures further downstream are more dependent upon the quantity being released at the particular time, however.

   Within the stream system a change in the types, total numbers and relative abundance of aquatic flora and fauna is expected. This may or may not be beneficial.

   Possible changes in streamside flora and fauna in combination with marked changes in summer flows, increased (or decreased) turbidity, formation of nuisance algal growths, and changed water temperatures may adversely (or beneficially) affect the very popular use of some of these streams for water contact sports during the summer months.

2) There will be some changes in the stream ecology and flora-fauna characteristics of adjacent lands. The most dramatic are those associated with the inundation itself. Usually that part of the reservoir site subject to prolonged flooding is cleared; however, vegetation in adjacent areas may undergo a significant change in environment. Streamside vegetation including that growing on natural flood plains is also sensitive to changes in hydrology. Two examples are the unique north coastal flood plains environment where redwoods rely on removal of competing vegetation to propagate and a more general situation where without scouring flows phreatophytes encroach on unused channels reducing their flood carrying capacity.

   Natural channels used in lieu of artificial channels to convey large quantities of water may be subject to other problems. High river stage sustained over long periods of time will cause increased seepage to adjacent lands. In order to prevent damage to soils and the vegetation from the higher ground-water table, drainage measures might be necessary.

3) Projects may reduce flood flows and possibly increase flows during dry summer months. The increased dependability of water supply might encourage more industrial development and population growth adjacent to the river channel and therefore more waste flows. These changes would require additional waste handling facilities in order to maintain water quality.

4) Eutrophication may be a problem in some potential source area watersheds because of high nutrient and temperature levels. Reservoir mixing and control of outflow may be sufficient to control eutrophication to acceptable levels.

   An example of potential mitigation of an existing enrichment problem is the proposed diversion of Eel River water from the English Ridge and Dos Rios projects through Clear Lake. This diversion scheme seems to promise beneficial water quality changes in Clear Lake, enhancing its recreational qualities and creating additional benefits.

   Management of all controllable upstream waste loads, such as those caused by recreational developments, is essential to inhibiting the eutrophication process in reservoir developments.

MUNICIPAL AND INDUSTRIAL WASTE TREATMENT AND RECLAMATION IN THE CENTRAL VALLEY (EXCLUDING THE SACRAMENTO AND STOCKTON METROPOLITAN AREAS)

The increase in population and waste loads throughout the valley and in the Fresno and Bakersfield metropolitan areas is projected to be large in future years. Meeting projected growth will require a severalfold increase in facility capacity by 2020 or earlier. Present waste handling is a combination of treatment and local land disposal. The waste handling systems will have to satisfy public health standards, and regional water quality control board discharge requirements and water quality control plans. The value of reclaimed sewage in decreasing ground-water overdrafts or supplementing surface supplies is potentially significant. Because of the large volume of waste waters, it may not be economical to operate special purpose farms for land disposal after treatment. Instead a feasible solution for waste handling might be waste water reclamation and conservation with subsequent discharge of these reclaimed waste waters to the regular irrigation supply canals.

Increased land disposal of treated municipal and industrial wastes together with percolation from agricultural lands may lead to localized problems of ground-water quality. An assessment of the likelihood, magnitude and a real extent of such problems has not been made. In such instances, alternative disposal systems at increased cost may be indicated.

Conservative constituents in wastes disposed upon land ultimately will be transported from the Central Valley either in surface streams, ground-water flow or surface drainage systems, if a mass balance is to be maintained. Transport of these residual wastes at acceptable concentrations has been included in required flow maintenance values present below.

Minimum total flow requirements for dissolved oxygen control have been projected for the lower San Joaquin River and selected tributaries (table 15). These flows should be adequate to provide dissolved oxygen levels enabling realization of the planned fisheries. Maintenance of these flows may be accomplished by a combination of approaches, including restriction of future applications to store or divert water during critical months and release of stored water for fishery and water quality purposes. The proposed Federal projects, including New Melones and Nashville Reservoirs and the East Side and Peripheral Canals, are being designed to meet these flow requirements. Flow maintenance for dissolved oxygen control appears to require lesser volumes of water than for total dissolved solids control in the lower

Table 15. Estimated Water Quality Control Flows for Dissolved Oxygen Control For Fishery Maintenance (c.f.s.)

River River Mile	1960 Base	 Canning Season	1980 Base	 Canning Season	2000 Base	 Canning Season	2020 Base	 Canning Season
San Joaquin								
110	5	10	5	15	15	30	15	30
91+	15	100	35	135	50	160	50	120
80	70	430	140	580	220	650	200	470
76+ (Vernalis)	110	720	220	970	360	1070	330	750
Stanislaus								
25	5	50	15	75	25	80	25	60
Cosumnes								
0-25	5	5	15	15	40	40	50	50

San Joaquin Valley; however, dissolved oxygen considerations may be determining in the middle reaches of the tributaries.

In most areas, problems resulting from wastes generated by recreationists can be avoided by careful and consistent application of existing treatment techniques. These consist of adequate provision of sanitary facilities and treatment at all recreation sites. In most cases, land disposal of effluents will be indicated since most locations will be too far from municipal facilities. Treatment techniques range from septic tanks with subsurface drainage to small "package plant" treatment systems with land application of effluents.

Any estimate of waste handling costs for the Central Valley without a specific physical design is likely to be in error, but the probable cost for the 5 million people (in 2020) outside the Delta-Sacramento-Stockton area in the Central Valley is this range: 200 to 500 million dollars for treatment and waste transport facilities to supplement the present type of systems. The Federal share of these costs would be between 30 percent and 55 percent based upon current statutes (60 to 275 million dollars).

MUNICIPAL AND INDUSTRIAL SEWERAGE IN SAN FRANCISCO BAY AREA

The San Francisco Bay-Delta Water Quality Control Program was created by the State Legislature in 1965. Its purpose was to determine the need for, and feasibility of, a comprehensive waste collection and disposal system serving the Bay-Delta area, as well as other measures for the maintenance of the quality of the waters. It was, in addition, to develop the basic features of a comprehensive plan for the control of water pollution.

The final report on the program was submitted to the State Water Resources Control Board by Kaiser Engineers and its associates on June 30, 1969. An abridged preliminary edition has also been published. The findings and recommendations of the State Board as forwarded to the State Legislature are included here as appendix 2.

The consultant's report evaluated "five distinctive water quality control systems. . .which are representative of the range of possible systems:

A local disposal system (nonregional)
A regional Central Bay disposal system
A regional combined Central Bay and ocean disposal system
A regional ocean disposal system
A regional reclamation - marine disposal system."

These systems were developed "to protect the water quality of the area, to serve all beneficial uses and to provide the greatest possible net economic and social returns to the people." This requirement approach has not developed a benefit-cost justification for the water quality "requirements" as public choices. The report recognizes this point and states:

> "In carrying out the first step, establishment of the beneficial uses to be protected might be based upon an economic evaluation which would demonstrate the tangible benefits that would accrue from these uses, or, conversely, demonstrate the tangible losses that would result from permitting existing uses to be discontinued. However, most of the benefits to be realized are not quantifiable in economic terms. What is the value, for example, of a view of fresh, clear water surrounded by white sand beaches or craggy rocks against a background of green mountains? And how does this value compare with that of a mud flat which, while unsightly to the eyes of many, produces the vital foods on which wildfowl and marine life depend?"

This quotation suggests a reason for a nonquantitative justification of the chosen program - that the realizable benefits are not "economic" goods. The net result of this 3-year, 3 million dollar study is a recommended system based on a noneconomic justification. That this extensive and expensive study was unable to provide any quantitative benefit cost answers serves as a precaution for the present modest study.

An interesting finding in comparing these five possible systems is that the costs to 1990 are approximately the same for each. After 1990 the local disposal system may be the most expensive. A comparison of costs to 1990 is shown in table 16, where the capacity and extent of the alternative systems is indicated.

A comparison of the five systems after 1990 is not found in the main report, as one option, the wastewater reclamation-marine disposal system, was recommended and the report discussion focused on this alternative. The cumulative cost estimated for this favored option may total 4.3 billion dollars by 2020 (1969 dollars) expended over the time period at an approximately uniform rate. The reclamation feature promises to reduce this large cost somewhat (20 percent) because the reclaimed water may have a value of $30/AF.

System construction would proceed in three phases: phase 1 to 1980, phase 2 completed by 1990, and phase 3 with developments after 1990. Phase 1 costs were studied most carefully and some financial details may be pertinent. The data in table 17

Table 16. Summary Comparison of Water Quality Control Systems for the Bay-Delta

(Status in 1990)

Source: State SF Bay-Delta Water Quality Control Program

Characteristic	Local Disposal System	Central Bay Disposal System	Central Bay-Ocean Disposal System[b]	Ocean Disposal System[b]	Reclamation-Marine Disposal System[b]
Major conveyance facilities (miles)	260	275	285	315	
Wastewater Treatment:					
Number of Plants	31	18	18	14	
1990 Capacity (mgd):					
Advanced Primary	9	9	435	786	
Chemical or secondary	598	675	585	329	
Tertiary	701	683	302	251	
Disposal of Wastewater (mgd):					
Disposal to Bay-Delta	1152	1152	795	515	
Disposal to Land	12	12	12	12	
Disposal to Ocean	25	25	382	662	
Total Accumulated Cost[a] (billions of 1969 dollars)	2.1	2.0	1.9	2.1	
Present Value (1970)[c] (billions of 1969 dollars)	2.1	1.9	1.8	1.9	

[a] Capital, operation and maintenance.

[b] Costs of the Ocean Disposal and Reclamation-Marine Disposal Systems are the same until after 1990.

[c] Includes capital, operation and maintenance through 1990 and continued operation, maintenance and replacement indefinitely after 1990.

Table 17. Allocation of Total Costs of Phase One With and Without Federal and State Aid

(Excluding Inplant Industrial Treatment)
(Millions of Dollars)

Source: State SF Bay Water Quality Control Program

Regional Costs without Aid			Costs with Maximum Federal Aid-No State Aid				Costs with Maximum Federal and State Aid				
Capital	O&M 5 Years 1975-80	Total	Regional			Federal (33%)[a]	Regional			Federal (55%)[a]	State (25%)[a]
			Capital	O&M	Total		Capital	O&M	Total		
Costs escalated to 1970-80											
$1,312	$118	$1,430	$907	$118	$1,025	$405	$332	$118	$450	$675	$305
Costs in 1969 Dollars											
804	66	870	564	66	630	240	214	66	280	405	185

[a] Percentage applies to capital costs exclusive of those for rights of way and assumption of outstanding debt on existing facilities.

adjusted for price inflation show the possible Federal share of phase 1 costs for the preferred system. These shares were calculated with two percentages (33 percent and 55 percent). The Federal share could be as much as 675 million dollars in the 1970-80 period. It should be noted that these costs do not include inplant industrial treatment facility costs estimated at 218 million dollars, but the system facilities will handle industrial wastes. In future years, about one quarter of the total waste volume may be "discrete industrial waste water flow" which is exclusive of cooling water flows.

A major recommendation concerned institutional arrangements to implement the technical solution:

> "A regional agency, either single or multi-purpose, must be formed as soon as possible to plan, design, construct and operate a comprehensive water pollution and water quality control system throughout the twelve counties comprising the Bay-Delta area."

Even though adoption of the recommended plan promises a cumulative expenditure of over 4 billion dollars, the per capita cost to a Bay area resident is not exorbitant. The projected bill in 1981, when phase 1 is complete, is about twice the present $7 per person annual sewerage service charge based on 1969 dollars without Federal or State aid. Adding phases 2 and 3 will increase this per capita cost probably to around $20 per capita (1969 dollars) in the year 2000.

What does the customer get for this new outlay? First, a bay that is generally "cleaner" than the present bay. This means he will enjoy aesthetic fishery preservation, recreation and public health benefits from this desirable water resource. These recreation benefits can be estimated. Valuations of present and future Bay use based on the "Senate Document No. 97" values infer an annual benefit around $7 per capita per year for the Bay area water-based recreation. This $7 per capita value can be increased in the future to reflect two factors: (a) that the present users will be realizing more benefits in the future (with this system compared to extensions of the present system) (b) people who are avoiding using the Bay waters at present because they feel it is polluted will be using the Bay when this new water quality control program is undertaken. Including these two factors (and others) can increase the per capita value to at least $15 per year, probably closer to $25 per capita. This new value then can be compared with that part of the $14 per capita cost that is attributable to water quality for aesthetics and recreation. This cost is probably represented by the present annual system costs of $7 per capita. Therefore, very crudely, the increased per capita cost of $7 per year may be offset by an equal increase in benefits in the near future. The benefit cost case for phases 2 and 3 appears to be equally supportable.

The growth of the Sacramento and Stockton metropolitan areas demonstrates the need for regional urban planning with centralized treatment and disposal facilities for the combined domestic and industrial wastes. The proximity of these cities to the Bay-Delta area warrants further investigation of possible inclusion in a San Francisco Bay-Delta system. Advanced waste treatment with local disposal/reclamation has been advocated by the Bay-Delta Program.

AGRICULTURAL WASTE TRANSPORT FROM THE TULARE AND SAN JOAQUIN BASINS

The need for drainage facilities to maintain the productivity of the San Joaquin Valley and especially the land-locked Tulare Basin has long been recognized. Agricultural drainage facilities are presently authorized as a part of the San Luis Unit of the Central Valley Project. Earlier plans to construct a larger joint State-Federal San Joaquin Master Drain were abandoned when the State decided not to proceed at this time. The need for drainage facilities in conjunction with the proposed East Side Canal is recognized and indeed the Secretary of Interior has indicated that resolution of the drainage problem will be necessary before the project can proceed. On the other hand, deferring the East Side only perpetuates ground-water overdraft which promotes further land subsidence which, in turn, makes drainage system construction more costly to construct and operate. No estimate is available for timing of additional drainage in the absence of additional importation of water; however, there is a current need for additional drainage to avoid abandonment of the ground water as a water supply.

The system design of each of these agricultural water drains includes a transportation system (including canals, flow regulating reservoirs, possible tunnels, pumping stations, etc.) and a waste treatment/reclamation system--depending upon the discharge location. DWR, USBR, and FWPCA are currently investigating various methods of treatment of agricultural drainage to be carried by the San Luis Drain prior to discharge into the Delta.

Costs vary by project design, but these cost estimates may be approximately correct at the present time:

System	Transport Costs	Treatment Costs	Cost Off-setting Benefits	Total Costs Less Benefits
Local Reuse in Valley	Residual waste for $10/AF treated	Demineralization at $55-100/AF	Sale of water for $30/AF	$35-80/AF
Bay-Delta Disposal	$15-20/AF	Denitrification at $10/AF or Tertiary at $30/AF	Salinity Repulsion at $5/AF?	$20-30/AF
Pacific Ocean Disposal in Monterey Bay	$50-65/AF	None possibly; if treated say $30/AF	?	$50-95/AF

The total volume of agricultural waste waters is predicted to exceed 500,000 acre-feet by 2010. Ultimate development in the San Joaquin and Tulare Basins will probably increase this volume. An estimate of this ultimate wastewater volume may be a return flow of 10 percent of the Tulare Basin water requirement of 10 MAF (million acre-feet) and 5 percent of the San Joaquin River Basin requirement of 4 MAF, a total of 1.2 MAF. Handling this million acre-foot volume may require a total capital expenditure in the 200-500 million dollar range to support ultimate development.

A complete agricultural waste handling system will include at least the three components of drains and drainage canals, treatment/reclamation and river transport schemes. The optimal combination of these three possible system components (and others) has not been determined.

The probable system capital investment on a present worth basis of 200-500 million dollars can be expected to produce benefits to agricultural users exceeding 500 million dollars. DWR benefit estimates for a 1-million-acre drainage problem area showed primary agricultural drainage benefits of 471 million dollars and public service cost savings of 40 million dollars at 4 percent interest, 100-year project life. The drainage system to serve ultimate development will possibly serve 1.7 million acres, so the benefit estimates would be proportionally increased. A precise benefit-cost comparison is not possible here, as the system design and probable staging are not available.

In addition to the inarea benefits for land drainage and public service benefits, the comprehensive drainage system which includes treatment and/or ocean disposal provide benefits in two other areas:

1) There can be an improvement in the lower San Joaquin River water quality (if certain water use assumptions are valid) because agricultural return flows will be diverted prior to reaching the stream. This possible increase in quality can mean some water use benefits along the lower San Joaquin River area, primarily to agricultural users or a decrease in flow maintenance requirements. Since drains are not likely to be 100 percent efficient, the need for supplemental streamflows has been considered below, but no precise requirements are estimated for most stream reaches as there are many potential localized problem areas which elude precise analysis.

2) Treatment of these agricultural drainage waters and subsequent discharge into the San Francisco Bay-Delta system can provide two types of water quality results. First the quantity of drain flow is large enough to aid in salinity repulsion at lower Delta outflows; this possible benefit decreases as Delta outflow increases at least for a disposal site near Antioch. A second consequence is that treatment of these drain waters to remove nitrogen will help to maintain a tolerable concentration of the biostimulant nitrogen in the waters of San Francisco Bay and the Delta. This treatment will cost less than $1 per capita for the Bay area residents (neglecting the issue of whether Bay area residents should bear such charges). The water quality benefits to compare with this cost are included in the overall benefits realizable from the regional waste handling system for the San Francisco Bay area. Adding this $1 cost to the previous $7 cost increment will only slightly change the favorable benefit-cost picture of the large system.

WATER QUALITY CONTROL BY FLOW MAINTENANCE IN THE SAN JOAQUIN BASIN

The San Joaquin River system is no longer capable of assimilating and transporting additional residual wastes free of economic and social costs. These waste disposal costs cannot be avoided. They will be incurred either through the installation and operation of adequate waste disposal systems or through economic and social losses of beneficial water uses resulting from increasing depletion of streamflow, deterioration of water quality and deterioration of the associated environment.

Data from recent years indicate that the trough of the San Joaquin River Valley has been functioning as a salt trap, i.e., the total quantity of dissolved solids entering the valley system is considerably more than that accountable in the outflow from the San Joaquin River at Vernalis. If the salt buildup continues, adverse effects on municipal, industrial, and agricultural water users in the San Joaquin Valley will continue to increase. Release of water for quality control purposes, installation of land drainage facilities or other means will be required to alleviate the problem and maintain the productive capacity of the valley. Thus, it is expected that the rate of dissolved solids leaving the San Joaquin River Basin will be increased to equal or exceed the rate of mineral solids input. An obvious alternative to use of the San Joaquin River as receiver of part of this dissolved solids load is the proposed San Joaquin Master Drain.

Based upon available information, the following annual flows would be required in the San Joaquin River downstream from the Stanislaus River in order to satisfy the criteria contained in the water quality standards:

	Level of Development			
	1960	1980	2000	2020
San Joaquin River at Vernalis	(1,000,000 acre-feet per year)			
With Master Waste Drain	1.1	1.5	1.8	1.9
Without Master Waste Drain	1.7	2.2	2.4	2.5

Projection of future flow at Vernalis is very sensitive to assumptions concerning construction and operation of water resource projects and drainage facilities, commitment of flow to other instream beneficial uses (such as fishery and recreation), protection of flow released for instream use against diversion for other purposes, etc. Several alternative developments have been considered, and, of these, one appears promising as a basis for consideration in further water quality management planning. This alternative contemplates the construction of projects as proposed herein, construction of a Master Drain, and fishery releases from the East Side Canal to various tributaries of the San Joaquin in amounts totaling 500,000 AF/year in 2020. Under these conditions the projected mean annual flow at Vernalis would slightly exceed the annual requirement with Master Drain service to the San Joaquin Basin. Seasonal flow distribution would not be adequate, however. In dry years (or, for that matter, in drier months of average runoff years), some additional flows for water quality control will be necessary, but the quantities required have not been estimated.

The monetary cost of flow maintenance for fishery, water quality control and other instream purposes, in the San Joaquin River and its tributaries has not been estimated but is believed to be low. No additional water is required; flows projected to be available in the Sacramento River at Sacramento and required for consumptive use within the Delta or for outflow from the Delta can be routed into the San Joaquin Valley through the Peripheral and East Side Canals prior to flowing into the Delta to accomplish the designated function. Thus, for example, a given volume of water could provide required fishery flow in the middle reach of a tributary to the San Joaquin River, dissolved oxygen control in the lower reach, total dissolved solids control and fishery flow in the lower San Joaquin River prior to consumptive use by Delta agriculture. The monetary cost would be incurred in terms of additional expenditures for electrical power and, perhaps, additional pumping plant and canal capacity. However, a detailed operation study might show that in dry years capacity in the proposed East Side Canal and associated regulating reservoirs and existing Delta-Mendota Canal and State Aqueduct in excess of that required to meet contractual obligations would be sufficient to convey all or most of the required water quality maintenance flow.

Historical salinity levels in the San Joaquin River near Vernalis together with projections of current quality under conditions of salt balance indicate the present need for flow maintenance to insure compliance with water quality standards.

Although this discussion is based upon flow maintenance to transport salts from the valley at concentrations no greater than that specified in the water quality standards, a requirement also exists to transport other refractory waste components at acceptable concentrations.

New Melones Dam will alleviate dissolved oxygen problems in the lower Stanislaus River as well as providing some relief from dissolved solids and oxygen problems in the lower San Joaquin. Additional flows are necessary for water quality maintenance in the San Joaquin and its other tributaries to meet present and growing future needs. On an interim basis, releases have been provided, upon occasion, through the Delta-Mendota Canal to relieve the most critical quality problem in the lower San Joaquin River. Although the Delta-Mendota Canal cannot provide relief to the tributaries, it and the California Aqueduct should be used to preserve water quality in the lower San Joaquin River, both as an interim measure and in conjunction with the East Side Canal as parts of a long term solution.

WATER QUALITY CONTROL BY FLOW MAINTENANCE THROUGH THE DELTA

Water quality control by freshwater flow maintenance is postulated as the most feasible means of controlling mineralization of Delta waters resulting from seawater incursion, agricultural drainage wastes from Delta lands, and transport of salts by inflowing streams and waste discharges, and as a means to supplement other actions to insure compliance with additional criteria in the water quality standards. Water quality by flow maintenance differs from the management systems discussed previously in one major respect: Flows and water quality are presently adequate and future action is largely directed toward preservation of quality adequate to support present and future beneficial uses (an antidegradation position).

The proposed Peripheral Canal and East Side Canal would both divert from the lower Sacramento River for consumptive use to the south and reduce inflow to the Delta proper. The Peripheral Canal would have also the capability to effectively manage water quality in the Delta. Elimination of Delta crossflow to the export pumping plants near Tracy also has significant water quality implications. Present controversy over these proposed projects would be effectively silenced if adequate assurances and commitments as to future water quality and supply in the Delta were included in plans and authorizations for projects resulting in a depletion of Delta outflow.

Certain elements which may ultimately comprise a management system are becoming apparent. The State Water Resources Control Board may place conditions upon the rights of DWR and USBR to divert directly or store water during periods when specified water quality criteria in the Delta are being exceeded. Such action in effect would define the existence of surplus waters available for capture. During those periods when surplus waters as so defined were not available, the release of stored water would be provided under the terms of a proposed contract among DWR, USBR, and the Delta Water Agency. An agreement between DWR and USBR has been drafted which defines the coordinated operation of the State Water Project and the Central Valley Project, including attainment of water quality objectives specified in the agreement. Finally the operational objectives of the Central Valley Project and its Peripheral Canal Unit may include the maintenance of quality criteria for total dissolved solids and chlorides approved by the Secretary of Interior; such expressions of intent could be contained in the authorizing legislation for the proposed project.

BENEFIT ANALYSIS

Benefit evaluation as desired for this study was not possible based on existing data and analysis. There are information limitations about water quality effects on beneficial uses, beneficial uses in each basin and project effects, both positive and negative. Methodology for monetary benefit evaluation particularly for some instream uses has not been developed and tested sufficiently to permit application in the present study. Therefore, an analysis of incremental benefits and costs of alternative water quality criteria has not been attempted for the Central Valley and related areas. A summary of major water quality control systems, beneficial uses and their monetary value is presented in table 18.

Review of benefit analysis as applied historically to projects in the study area led to certain conclusions, including these:

1) There is some reasonable ceiling on beneficial use estimates, e.g., the present individual project approach to recreation use projections may lead to unrealistically high total recreation projections if all project benefits were totaled.

2) The water users reaction to a change in water quality may be to move his location of activity. If a water pollution problem is localized a recreationist's reaction, for example, may be to move a few miles---therefore, his only change may be location and the incidental costs of moving. However, when the water quality deteriorates over a wide area these movements or reactions to avoid water pollution may involve substantial amounts of money and time. In this latter case the detriments of water pollution can be large, whereas a localized problem--if water quality is satisfactory nearby--will have much less economic consequence. A measure of the detriment is the difference in cost to make the consumer equally well-off at another location.

3) Water quality in several areas is "threatened" by several sources of pollution. For instance, it appears that the separate, untreated waste discharges from either (a) municipal and industrial water users or (b) agricultural waste drains could be sufficient in themselves to seriously diminish the anadromous fishery resource in the Bay-Delta area. This multiplicity of large waste sources seems to dictate an "all or none" approach to waste control for the San Francisco Bay-Delta area, where all sources must be controlled so no serious ecological consequences and subsequent detriments will affect present beneficial users of San Francisco Bay-Delta waters.

4) Because of this "all or none" pollution control program need, it appears that an overall picture of the total benefits to be gained from controlling all sources should be considered

Table 18. Estimated Value of Beneficial Uses Preserved by Major Water Quality Management Systems

Basin	Major Water Quality Management Systems[a]	Beneficial Uses[b]	Estimated Value of Beneficial Uses
San Francisco Bay	(1-6)	(C-F)	1990 value for (C-F), from (1-6) = \$169M/Yr. 2020 value for (C-F), from (1-6) = \$272M/Yr.
Delta	(1-6)	(A-F)	50 year average value (A-E) from (3) = \$16.5M/Yr.
San Joaquin	(2-6)	(A-F)	Better water quality in San Joaquin River. Some benefit to (A) and (B) included in Delta estimates.
Tulare	(2-6)	(A-B)	Present worth greater than \$500M for (A).
Sacramento Valley	(4,5)	(A-F)	Not evaluated.
North Coastal	(5)	(A-F)	Not evaluated.
Southern California	(2-5)	(A-B)	Not evaluated.

[a] Major Water Quality Management Systems
- (1) San Francisco Bay-Delta Sewerage
- (2) Tulare-San Joaquin Drainage
- (3) Delta Flow Maintenance
- (4) Central Valley M&I Waste Systems
- (5) Reservoir and Conveyance Systems
- (6) San Joaquin River Flow Maintenance

[b] Beneficial Uses
- (A) Agricultural production and water supply
- (B) M&I water supply
- (C) Fishery
- (D) Flora and fauna
- (E) Recreation
- (F) Aesthetics and amenities

(hence the constraints on benefit estimates) even if the approach is crude; otherwise the same set of benefits may be used to justify several different pollution control programs.

5) Unfortunately the complex character of the Bay-Delta and other problems has limited incremental analysis which would search for some optimal combination of waste control program and benefits. The only easily identified combinations of benefits and costs are the "polar" solutions, i.e., no pollution control and no benefits or an antidegradation or enhancement policy and essentially unimpaired use of the Bay-Delta waters.

An important part of the analysis of alternative water quality objectives is the evaluation of benefits. Typically we distinguish benefits by major type: withdrawal and inplace. The water quality benefits for the withdrawal users are usually estimated by a variation on the theme that changing water quality can affect the productive efficiency of typical withdrawal users such as agriculture or industry. The specific effect can be measured as an income change due to increased production costs, lessened production volume, efficiency or quality, etc. This change in costs of water use also applies to domestic users, who adapt to water quality changes by additional expenditures: water softening or bottled water for example. So the change in water use costs provides another means of benefit evaluation--arguing that a cost reduction amounts to an income increase (or no reduction in income).

However useful these income approaches might be for typical withdrawal users like agriculture, industry or domestic consumption --the income approach is rarely used to evaluate the water quality benefits for inplace, nonwithdrawal uses such as water-based recreation (with the exception of regional income from tourists models). The typical model used for recreation benefits is a variation on a rental value model--estimating the entrepreneurial income from ownership of the particular site or recreational resource. Economists have argued against income models that purport to evaluate recreational benefits. There are good reasons to accept the economists' reasoning supporting a rental value model for water-based recreation values. But there are also reasons to ask whether rental value models are appropriate to use for comparison with benefits estimated using income models.

The reason for questioning a comparison is the probable (incompatibility of numbers. For example, the current project studies for the Central Valley claim an agricultural benefit of between $60 and $130 per acre-foot of water supply, including indirect benefits. This value is derived from an income model. But the calculated ability to pay is usually much lower--typically in the $7 to $22/AF range for recent projects. This value is derived from payment capacity studies. So the feasibility report reviewer is actually presented with two numbers: a benefit of about $100/AF, and an ability (or willingness) to pay of about $15/AF.

The rental value approach to recreation benefits has been discussed in the economics literature. The usual study is based on estimating an admission charge for site access, or imputing a consumers surplus, with both methods based on the differences between individual recreationist's expenditures. The benefits estimated by these methods are typically rather low--in the $0.50 to $6 per day range, usually around $1 per participation day for the usual outdoor recreation activities like swimming, hiking, etc. In contrast to these low values of benefits is the much higher value of the potential income foregone by choosing leisure and recreation rather than work. The average worker may earn around $25/day, and dividing this by three (roughly representing the ratio of workers to total population) results in an $8/day/person estimate of potential income foregone when a family Father chooses leisure rather than work. This value is substantially higher than the average $1/day recreation benefit derived from a rental value model. Economists would argue against this "income foregone" model and claim that it overstates benefits. Compared to rental value model benefits the estimated benefits are high. So again this is an example of incompatible benefit estimates for the same situation.

The point should be clear here--there are at least two approaches to benefit evaluation: (1) an income model and (2) a rental value model. The difference in estimates using each method is usually substantial. This difference must be recognized because it can lead to distorted allocations of water use. For instance, in a situation where withdrawal and inplace users are competing for a limited supply, appropriation by one class of users may exclude use by the other class. If the benefits for each class of water user are based on incompatible models, the allocation will be distorted and biased.

The estimates for both benefits and cost are qualified by probabilistic statement, e.g., the "average" or "high" estimate, the "expected" cost, etc. Because of this uncertainty about estimates there is no assurance that benefits exceed costs even when the benefit cost ratio is greater than 1.0. Recognizing this uncertainty, the situation can be rationalized by assuming that construction of several "favorable" projects will increase our probability that, in an overall accounting, the net benefits are positive. But this long run averaging of project benefits hides the fact that some projects or project related effects may be detrimental to specific sectors of our economic or biological world.

Although the benefit cost ratio may be favorable overall, there may be some people who suffer economic detriments from project effects, and often these people who have been made "worse off" were not compensated by those who were made "better off" by the project. In instances where there is uncertainty concerning potential detriments, a wait-and-see plan which would assure remedial action or compensation may be an appropriate compromise. The proposed flexible plan would necessarily include sufficient guarantees or assurances about remedial action or compensation. For storage projects, a part of the project yield could be reserved for future commitment to either consumptive use or environmental control based upon evaluation of operating experience.

The effects of some projects is to cause predictable changes in the ecology--sometimes beneficial, but also detrimental. These ecological consequences are sometimes converted into economic consequences when the affected flora or fauna have some economic value to man. But there are some situations where living animals have little economic value to man. Examples would be the protected shorebirds and waterfowl where hunting or trapping is carefully controlled. These animals are not given an economic vote, so they are not directly provided representation in the present system of law and economics that allocates resources to beneficial users. But these animals need protection, and the present resource decision-making system may not provide adequate protection.

Including equity and ethical issues in a systems design usually can be accomplished by introducing constraints on the feasible set of alternatives. Examples of constraints that preserve rights (and equity) and protect wildlife (hence ethical) would be these:

1) No system will be considered which would diminish some party's social welfare, unless this system specifically provides for compensating the affected parties;

2) No system will be considered which would change the physical environment to the overall detriment of animals in the ecological system.

These are strong constraints, but they are compatible with contemporary legal and ethical philosophies with regard to resource allocation.

New and broadened bases for water resource development formulation and evaluation are now under preparation by the Water Resources Council. The new bases will not only consider national efficiency but will also consider environmental, social well-being and regional development benefits. It is believed that these new measures will greatly assist better development of the Central Valley water resources.

VI. FURTHER APPRAISAL OF DEVELOPMENT IN THE CENTRAL VALLEY

LIMITATIONS OF THE ANALYSIS

The shape and content of this study were largely dictated by several major limitations. Certain of these were known before the study began while others became apparent as the study progressed.

Study Constraints

Time and manpower constraints restricted this study to a limited-scope, exploratory effort, based upon existing data and analysis. Of necessity only major developments have been analyzed.

Many proposed projects in addition to those considered here affect only the local stream on which they are located. They are too small to have any significant effect on the overall Central Valley environment, their individual effect being less than the accuracy of the overall valley analysis. The local impact however may be very significant and must be evaluated in a more comprehensive study.

Unsatisfactory Data and Incompatible Analyses

Available data and analyses are not satisfactory for the purposes of this study. In order to compensate for these deficiencies, data omissions must be supplemented by analysis or judgment based on other data that may not be entirely consistent, compatible or correct for this study situation. For instance, a very important factor in these water quality predictions is the quantity and quality of return flows from agricultural use. Unfortunately these flows are difficult to observe, as they often take the form of underground seepage rather than directly observable flow in a drainage pipe or canal. Data on ground and surface water hydrologies from different sources often lead to inconsistent hydrologic balances. USGS classification of flow data as "excellent" has a plus or minus accuracy of 5 percent which is very significant when considering annual flows of 30 million acre-feet for the Central Valley.

The differences between two sets of seemingly equally good analyses of the same or similar situations can be surprising. These differences can be attributed to numerous factors including:

1) The data used may be different, so dissimilar analyses can be expected,

2) Variations in the mathematical structure of the analytical models used often leads to different analytical results,

3) Different assumptions about the system or situation being studied can lead to further variations in analysis,

4) Predictions based on extrapolation of present trends are sensitive to changes with time.

The Whole System is Usually Not Equal to the Sum of Its Parts

Analysis of project effects when developed on an individual project basis cannot be cumulated or added to give a fair and realistic appraisal of alternative system developments. For instance, some project detriments may be omitted in an analysis while a single set of benefits may be attributed to several projects. A fundamental problem here is that most data gathering and analysis has been performed by individual agencies for specific project studies rather than as part of a comprehensive basin wide plan to serve many types of water users. A more comprehensive appraisal must be undertaken, as it is becoming obvious that the whole system is not equal to the sum of its parts.

The analytical work necessary to accurately evaluate the joint consequences of several projects considered simultaneously becomes increasingly complex. The problems of data and analytical models that limit confidence in individual project analysis are even more evident in multi-project analysis. These deficiencies in data and analytical models for large, complex systems may frustrate adequate analysis. The lack of an adequate description of the overall Central Valley system precludes a sophisticated analytical effort, and therefore, this study has led to an awkward position - a feeling that the present state of analysis is inadequate but an inability to develop a definitely better analysis without substantial effort.

Unquantified Environmental Consequences

Economic prosperity and development associated with a rich and complex variety of consumer goods has been accompanied by an expanding number of waste products and a concern for "new" types of pollution. The problems of nutrients and pesticides are now familiar and often appear in current water quality standards. Most recently attention is being focused on controlling other environmental factors as well. Current examples include standards for sublethal toxicity (which includes pesticides) and temperature limits on waste discharges. Much additional work is required in developing economic evaluation models. But an exhaustive listing can only serve to reinforce this point--many of the environmental consequences of project developments and water use are not well known, so a complete appraisal of project effects is not possible. Often these project consequences are discovered after construction.

FUTURE PLANNING

In some cases, several development projects have caused a cumulative effect on the environment, which in turn has required construction of another project to maintain beneficial water uses and preserve or enhance environmental quality. While these projects may seem necessary, they could perhaps have been avoided by better planning. This study has been constrained by the several limitations listed above: limited time and manpower, unsatisfactory data and analytical models, and problems identifying all the project effects. These same factors undoubtedly limited previous studies also. In the past, superior projects (as determined by hindsight) were not constructed in some instances, although they were presented as alternatives in the planning stage, simply because the final arbiter had his own criteria or biases. More often than not, economic efficiency in the narrowest sense prevailed over all other considerations. A need for future rescue projects may arise.

It must be remembered that much of the development of the water and land resources of the Central Valley occurred before the consideration of environmental effects was recognized as a planning purpose. Given today's knowledge and constraints, a better planning and development job could have been achieved.

The main focus of this short study has been to test the hypothesis that: Further development in the Central Valley area will cause more water quality-quantity related problems. The answer to this hypothesis is a definite yes with a qualifying statement that the impact can be mitigated by certain actions. These remedial or preventive actions to maintain the water quality-quantity allocations in beneficial proportions will be an additional cost to be added to the water development and waste management costs. These additional costs lead to another hypothesis: Are further water resources developments justified when they include necessary remedial or preventive actions? The answer to this question is most likely yes, which means there is a reasonable expectation for benefit-cost ratios exceeding one. In addition, separate tests of each project component will probably support these features.

It should be pointed out that some effects of existing projects were not recognized until after projects were in operation. Some of the project effects have been overlooked, or unanticipated - such as the potential nutrient and pesticide problems, or improving habitat for salmon spawning.

Can a better system design be realized through a planning process more inclusive of these additional effects? This is a complex hypothesis to test, and it should be acknowledged that even if such a process was undertaken there would be enormous implementation problems, as land and water use are controlled by a loosely coordinated collection of private and public bodies, including local, county, State and Federal units of government. Because this and previous studies have not been directed toward the development of an optimal system design, the recommendations are not the result of a set of optimality calculations. Rather they result from a factual analysis supplemented by judgment based on limited experience.

The first recommendation is for a comprehensive master waste handling system for the Central Valley, as follows:

1) The drainage problems of the San Joaquin Valley and Tulare Basin need a near future solution if the present and future beneficial uses are to be protected. The drainage system should be an integral part of the facilities for development of additional water supplies.

2) This waste handling system should not create pollution or other environmental quality problems in the disposal area. Specific criteria must be established for this objective.

3) A most important feature of any waste handling plan is the cost-sharing formula. Some observers of the Central Valley development planning would state that realizing agreement on the problems of cost sharing, i.e., who pays for which features, is more difficult a task than achieving consensus on the physical configuration of a project. This cost-sharing problem is particularly perplexing in a situation like drainage in the San Joaquin Valley where many people benefit; but it is difficult to evaluate and explain the individuals' benefits convincingly enough to cause sufficient subscription to the project costs, so a project may not be financially feasible. Difficulties encountered by the California Department of Water Resources in obtaining agreement on cost sharing for the San Joaquin Valley Master Drain is the best current example. The problem of agreement on cost sharing might be readily resolved by including drainage as a part of the water supply facilities and including a surcharge on the delivery price of water.

Another set of recommendations concerns improving dry year water allocation rules. The present "shortage" rules can result in the impact of dry year flows being felt by only a few water users - the hardship of low flow is not shared equally. Especially affected are instream water users who have no water right protection of their flow requirements. Proposed allocation would provide for society to purchase rights for water from withdrawal users in the occasional dry years to maintain streamflow. Water users who sell their surface water rights may be able to pump additional ground water to substitute for lost diversions. The impact of increased ground-water pumping would have to be taken into account.

A final set of recommendations revolves around the theme that the Federal Government should undertake more thorough identification and analysis of project and operational effects to permit anticipation and mitigation of potential difficulties. Such analysis should also investigate institutional factors, cost-sharing arrangements and water shortage allocation rules.

The present arrangement of multiple water resource agencies, with some interagency cooperation, does not necessarily assure an optimal plan. While it should be clear that there are enormously difficult problems in developing optimal plans and management systems, the rewards of doing so are significant. Specific gains can be achieved in these areas:

1) Project Selection - A more thorough analysis of the possible project alternatives is warranted - the further development of water shortage rules being an example.

2) Project Details - The inclusion of drainage disposal and waste management facilities should be an integral part of the development plans, including alternatives of scale and timing.

3) Contingency planning or adaptation to unanticipated consequences - Problem of remedial or alternative actions in case of unanticipated consequences - such as environmental pollution or adverse effects on ecology should be included.

FUTURE STUDIES

During the course of this study it became apparent that the time and manpower have been too limited to satisfy the desired objectives. Definitive answers to the questions asked by the Bureau of the Budget cannot be given. Even a detailed and expensive study of the Central Valley area problems might not develop all of the answers. Many of the problems are the result of changing technology, laws, goals and affluence. Measuring and monitoring changes in the environment and proper analysis of the data probably will do more in setting the stage for better planning to realistically meet problems that will occur. Particular areas for further study include:

1) Stream hydrology and water balances with future project development sequences,

2) More quantification of environmental relationships between water quality, quantity and beneficial uses,

3) Development of realistic and comprehensive economic methodology to evaluate environmental and beneficial use consequences,

4) An exploration of noneconomic issues in water resource decision making, particularly questions such as interagency relationships and the effect of rights and equity constraints on water use.

A goal of future studies would be to improve on present analysis - so computer models and modern management information systems would be developed. These new tools would insure permanent improvements in management and decision making, rather than a one time only analysis, as they could be used in day-to-day work after the studies were completed. This special effort could amount to a "quantum jump" improvement in analytical comprehensiveness and speed, and would be a substitute for increasing technical staffs to handle future work loads.

APPENDIX 1

CENTRAL VALLEY WATER RESOURCE STUDY

Outline of Plan of Study

I. Purpose

There is growing concern over water quality in the Central Valley of California, particularly in the delta area. Federal actions on both water quality standards and water project development are of major significance in future water management policy. The purpose of this study is to provide a better basis to make decisions with respect to Federal water development and water quality control plans, projects, and programs in the Central Valley in the immediate and short-term future, 1969-1980. Specifically, the study is designed to:

(a) indicate the interrelationships between Federal and all other water development and water quality control and management programs;

(b) explore alternative policies and programs of water development and quality control to meet the growing needs of the Valley;

(c) assess the benefits and costs of present plans for future programs and of those alternative policies and programs;

(d) evaluate the effects of each future major water development decision on water quality and determine the optimum means and costs of alleviating any detrimental effects;

(e) explore alternative levels of water quality standards and determine effects of such variation upon plans and costs of both Federal water development and water quality control measures; and

(f) examine the effect of alternative Federal water pricing policies upon the physical demand for and use of water, and the resulting economic and social effects.

The study will reflect projected changes in water development and use and the impact on water supplies and water quality from future agricultural, municipal, industrial, economic, and social growth in the Central Valley. Study emphasis will center on the impacts of the Federal development program. Developments in the State, local, or private sectors generally are not dependent upon Federal decisions; however, they will be included, scheduled, and considered in evaluation of Federal water development programs.

II. The Central Valley and Its Economy

- A. Geographic and physical description
- B. Pattern of settlement, land use, and economic development
- C. Development and use of surface and ground water supplies
- D. The agricultural economy--irrigated acreage, land use, crop and commodity production and value
- E. Pattern of development and growth of nonagricultural economy
- F. Population--urban; rural
- G. Economic projections--population, employment and income

III. Study Plan

- A. An inventory of developed water resources (existing, under construction and authorized in 1968) which will include:
  - 1. Inventory of local, State and Federal developments characterized into classes including:
    - a. water source development--ground; surface
    - b. transportation facilities
    - c. others including waste drains, off-channel storage, etc.
  - 2. Capital invested in each project
  - 3. Existing water rates (Federal, State and other)
  - 4. Contractual water quantity and quality commitment
  - 5. Current water quality burden (quantity of water required) including water rights description
  - 6. Estimate of the remaining undeveloped supply--Central Valley and North Coast
  - 7. Historical sketch of hydrology (including water quality).

B. Water resources projects proposed for authorization through 1980:

1. Schedule of total water demands--1980, 2000, 2020

2. Schedule of project additions (local, State and Federal)

3. Schedule of capital investment, required annual operation, maintenance and replacement costs

4. Estimated benefits

5. Water pricing and repayment outlook

6. Impact of each project on hydrology of the entire system, including drainage.

C. An inventory of present and potential water uses, both withdrawal and in-stream and including water quality and quantity requirements identified by project and delivery volumes for:

   a. agricultural uses
   b. municipal uses
   c. industrial uses
   d. other uses.

This inventory will be used to prepare a materials balance projection for purposes of estimating water quality.

D. Predictions of water quality at various locations in the system as a function of predictions from materials balance and hydrology. Materials balance predictions will be based on two approaches:

1. Systematic construction from empirical theory--for example, salt concentration in return flow is a function of salt concentrations in applied waters and water consumption, estimates, deterioration of soil, introduction to drainage waters by agricultural amendments and effects of seasonal accumulations;

2. Historical data on the relationship between water development, water use, and water quality.

E. Study of means and costs and benefits of satisfying various suggested water quality standards at specified points in the system

1. Available techniques evaluated for water quality improvement will include:

   a. dilution
   b. transportation
   c. treatment and reclamation
   d. other methods
   e. combination of the above alternatives.

2. The costs in terms of money and/or water of achieving water quality standards through the combination of one or more alternative waste handling methods will be estimated to allow appraisal of the cost of water quality standards.

3. The benefit (social costs avoided) of achieving water quality standards at selected locations in the Central Valley system will be appraised in terms of economic and noneconomic variables.

F. Limitations on the analysis

G. Alternative pricing structures

The effect of an escalating series of water prices would fall largely on irrigated agriculture. In the main municipal water users will pay any price for water within reason. There are few heavy water use industries that obtain water from the Central Valley Project and normally the cost of water is but a small factor in the industrial processes found in the Valley. As the price of irrigation water is raised there will be less use of Central Valley Project water and a greater continued overuse of ground water. Eventually this will lead to reduction of irrigated agriculture as pump lifts get too high. The extent of development of new lands in irrigated agriculture will vary inversely with price of water.

The study will have two basic objectives: (1) a projection of the physical situation within a range of water prices, and (2) the economic and social impacts associated with each level of prices. The time constraints of the study may not permit a thorough quantitative analysis of (1) or (2). However, a full qualitative description will be developed together with as much quantitative projection as possible.

A supplementary study also will be carried out in which prices for power and municipal and industrial water will be varied to evaluate the effect on Central Valley Project revenues available to support overall basin development.

APPENDIX 2

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STATE OF CALIFORNIA-THE RESOURCES AGENCY RONALD REAGAN, GOVERNOR

STATE WATER RESOURCES CONTROL BOARD Phone 445-3993
Room 1140, Resources Building
1416 Ninth Street, Sacramento 95814

Kerry W. Mulligan, Chairman
W. A. Alexander, Vice Chairman
N. B. Hume, Member
E. F. Dibble, Member
Ronald B. Robie, Member
Jerome B. Gilbert, Executive Officer

July 14, 1969

TO THE MEMBERS OF THE STATE LEGISLATURE

The State Water Resources Control Board is pleased to transmit to you its findings and recommendations on a unique and historic planning program to protect our State's waters, the San Francisco Bay-Delta Water Quality Control Program. In response to 1965 legislation (Chapter 1351, Statutes of 1965, Regular Session) the Board employed engineering and scientific experts headed by Kaiser Engineers and including Engineering-Science, Inc., Water Resources Engineers and Dr. Erman A. Pearson as principal consultant.

The Kaiser group completed its work earlier this year. An abridged edition of their report was furnished to you previously. We are transmitting with this letter the report of the Program's eminent Board of Consultants headed by John D. Parkhurst of Los Angeles. It is an excellent document and we commend it to you.

The Bay-Delta Program in which the State and Federal Governments have invested nearly $3,000,000 has been coordinated and supervised by the Board's Bay-Delta staff.

There has been in this Program, for the first time in California if not in the entire country, an integrated effort utilizing skills from a number of disciplines to consider social and economic as well as physical and biological aspects relevant to the development of a comprehensive water quality management program. New criteria for measuring pollutional effects relating directly to the aquatic environment have been developed. A bold and imaginative approach is provided in the basic concepts of the recommended plan for control of municipal and industrial wastewater pollution.

The Board, the California Water Commission and the Board of Consultants have held four lengthy hearings on the Kaiser report at San Jose, Martinez, San Francisco and Sacramento. (The Board has coordinated its review of the hearings with the California Water Commission. The recommendations of the Commission will be included in the Program summary report.)

Virtually all witnesses at these hearings supported the continuation of studies and planning for a consolidated approach to the water quality problems of the Bay and Delta, although some concern was expressed over the Program's new scientific concepts about the cause of long-term damage to fishlife and of algae growth problems in the landward extremities of the Bay-Delta estuary.

While this study has considered the Bay-Delta area, through which flows the drainage of 40 percent of the land area of the State of California, it has profound lessons for other areas of the State. The Legislature has directed that water pollution control and projects for the use of water will be regulated together by this Board. That is one side of the coin. The other side is providing local government with the institutions and financing to work cooperatively in groups or under the umbrella of an areawide agency to actually build the treatment plants and wastewater interceptors to protect this State's receiving waters for all the uses that the people of California wish to make of them.

BASIC FINDINGS OF THE STATE WATER RESOURCES CONTROL BOARD

1. Municipal and industrial wastewaters have been identified as the principal cause of significant water quality deterioration in San Francisco Bay and the Delta today. The increase in these discharges in the years ahead will result in progressive damage to the environment unless effective control measures are implemented.

2. To be effective, a water quality control program must consider, in addition to the traditional measures of quality, the actual effect upon the living aquatic resource that is to be protected. In this regard the toxic and biostimulating properties of wastewaters are of major importance.

3. Individual cities and industries--no matter how well intentioned their efforts--have not been able to prevent pollution and they cannot on an individual basis be expected to adequately cope with water quality problems in the future.

4. The concept developed in the Bay-Delta Program for an integrated areawide plan providing for transport of treated wastewaters from landward extremities of the estuary initially to the central part of San Francisco Bay and perhaps ultimately to the ocean is sound.

5. For an additional cost of $25 per year per household over present pollution control expenditures--an amount less than 10% of the average expenditure for all utilities and about one-third the present cost for water supply--a coordinated areawide plan can be implemented in the Bay area. Such a plan would guarantee a much greater degree of protection to the Bay's water quality yet would cost no more than the continuation of the present fragmented go-it-alone basis with its higher risk to the environment.

6. An agency to refine and implement a comprehensive plan is urgently needed for the Bay area. Although the Bay-Delta Program has developed the basic features of a plan for water quality control in the Bay and Delta areas, there is no governmental entity capable of completing the detailed planning and implementing a coordinated areawide program. The creation of a multi-county agency for an areawide approach in the Delta should be given further study.

7. Source control of long-lived pesticides is an essential element of any plan to maintain and enhance water quality.

8. The Board of Consultants and Kaiser Engineers have recommended new actions by the State Board to accompany implementation of any plan to maintain and enhance water quality in the Bay-Delta area. This Board has already taken steps to implement some of these actions and others will be of high priority for the Board in the months ahead.

Bay area cities and industries are growing and new chemicals are being added to the waters of the State. While this year's session of the Legislature has given the State Water Resources Control Board and Regional Water Quality Control Boards more authority and expanded investigative, planning and enforcement programs, the physical works to end pollution caused by literally hundreds of municipal and industrial wastewater discharges must still be built. This study has shown that every day's delay in constructing coordinated systems will make the task more difficult and expensive.

RECOMMENDATIONS OF THE STATE WATER RESOURCES CONTROL BOARD

1. The Legislature should adopt at its next session enabling legislation for the creation of a permanent service agency having authority to plan, finance, construct and operate facilities for interception, treatment, reclamation, and disposal of municipal and industrial wastewaters in the nine Bay area counties.

   In the Board's judgment this effort should be coordinated with consideration of a multi-purpose agency for the Bay area. However, it should be capable of separate implementation if there is no action taken to create a multi-purpose agency.

2. The Legislature should provide for the continuation of the Bay-Delta Water Quality Control Program on an interim basis until the permanent service agency is created.

Initially those Bay-Delta planning functions relating to a comprehensive water pollution control system for the Bay area should be transferred from the State Board to the Bay Conservation and Development Commission. BCDC should continue the planning until such time as a single or multi-purpose service agency is established. The interim planning should include work on program details and, especially, coordination with local needs and programs.

3. The Legislature should act now to control long-lived pesticides at their source, regulate their handling, and insure that criteria for their acceptance and use are established by environmental protection experts from resources and health agencies.

   The Program's determination that municipal and industrial wastewaters contribute substantially to the pesticide problem makes new legislation in this field essential. The Board shares the public concern about both the known and uncertain effects of pesticides on the environment.

4. The Legislature should recognize as a state responsibility, and should provide adequate funding for, completion of urgently needed studies of the toxic properties of municipal and industrial wastewaters, biostimulating materials in wastewaters that cause undesirable algae growths, and Bay dispersion capability.

   The Program identified several critical studies that should be started immediately since their results are needed to make sound planning decisions and to develop meaningful enforcement programs.

We believe the report and our recommendations show conclusively the need of a strong action program to save the Bay and Delta area waters. We further believe that only through an areawide agency can this objective be accomplished. The people of California have the opportunity now to preserve the Bay from the pollution, stench and death to aquatic life that will inevitably occur if we do not develop a coordinated program to handle the wastewater from this area which will have 15 million people after the turn of the century. The State Board stands ready to work with you individually and with your committees to make the State's investment in this significant effort pay dividends for future generations of Californians.

Sincerely,

(s) Kerry W. Mulligan

Kerry W. Mulligan
Chairman

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

[illegible]

Dear Governor Reagan:

[illegible]

APPENDIX 3

[illegible]

[illegible]

[illegible]

/COPY/

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

JAN 9, 1969

Dear Governor Reagan:

I am pleased to inform you that, with the exceptions and considerations stated below, I have approved the water quality standards of the State of California based upon my determination that they are consistent with the protection of the public health and welfare, the enhancement of the quality of the water, and the purposes of the Federal Water Pollution Control Act, as provided by Section 10(c)(3) of that Act. Accordingly, the standards as approved, which include thirty-one of the thirty-two Water Quality Control Policies submitted in June 1967, State Board Resolutions 67-36 through 67-41 and other adenda submitted by Mr. Irving Goldfeder's letter of November 21, 1967, and State Board Resolutions 68-16 and 68-17 submitted by Mr. George B. Maul's letter of November 21, 1968, are those applicable under the Act to the interstate waters of California. To clarify a difference in terminology, the State Board defined "Water Quality Control Policy" as used by the State to have the same meaning as "water quality standards" as used in the Federal Act. My approval of the California standards is based on this definition of terms.

I would like to commend your State Water Resources Control Board, its predecessor, the State Water Quality Control Board, and your Regional Water Quality Control Boards for a fine job of standards-setting and for their excellent cooperation in working with the Federal Water Pollution Control Administration in developing and revising the State's standards. The California standards are good ones, well documented and, with few exceptions, fully adequate to protect the quality and uses of your interstate waters. In particular, I am gratified by the adoption of a policy to protect high quality waters as a part of your State's enforceable standards. In my opinion, this policy, coupled with the high standards established for Lake Tahoe and certain other waters of your State, will prove to be of great value in conserving the present high quality of these waters for future generations.

During the past year, your State Water Resources Control Board and the Federal Water Pollution Control Administration have worked together to resolve differences over a number of items of the originally-submitted standards. Most of these issues have been resolved, and of those remaining I have excepted three items from my approval and recommended that certain actions be taken on the others.

I have excepted from approval the Water Quality Control Policy for Harbors, Marinas and Tidal Prisms of Los Angeles and Ventura Counties. I note that the Los Angeles Regional Water Quality Control Board has recently, adopted significant changes of this policy, but that the State Board has not yet acted on these revisions. Therefore, I am deferring consideration of this policy pending completion of the State Board's action.

I have also excepted from approval all of the water quality objectives for temperature contained in the policies I have approved. These objectives are expressed in narrative terms or do not provide numerical temperature limits which we believe are necessary to effectively administer control over thermal pollution. I note that the State Board asked the State Department of Fish and Game to survey the present thermal character of interstate waters and to develop and recommend appropriate numerical temperature objectives. Further, I am informed that this study has been completed and that the State and Regional Boards will soon be considering the Fish and Game Department's recommendations. I am pleased with this positive approach, and we will look forward to receiving modifications of the temperature objectives.

Lastly, I have excepted from approval the minimum dissolved oxygen limit of 4.5 mg/l established for the nearshore coastal waters of the Santa Ana Region. We believe that a limit of 5 mg/l would more closely define natural water quality conditions, when not affected by deep ocean water upwelling, and would be consistent with the limits set for the other nearshore coastal waters of California. I recommend the adoption of this higher limit by your State and Regional Boards.

The Water Quality Control Policy for Sacramento-San Joaquin Delta adopted and submitted in June 1967 established salinity standards which we found inadequate to protect present municipal, industrial, agricultural and fishery uses. Because of the substantial Federal and local interest regarding this estuary, I appointed a Department of the Interior task force to consider this matter and, after hearing the Contra Costa representatives and studying other pertinent factors, this task force developed proposed salinity standards designed to protect existing water uses. These proposed standards were made available to your State Board for its consideration, and that body, after public hearings and staff evaluation, on October 24, 1968, adopted by Resolution 68-17 "The Supplemental Water Quality Control Policy for Sacramento-San Joaquin Delta." This Supplemental Policy augments and strengthens the salinity standards of the June 1967 Policy, but it differs significantly from the proposed standards which the Interior task force developed in that important water uses of the Delta are left unprotected. These are the spawning of striped bass and the municipal, industrial and agricultural water uses of the western part of the Delta. The State Board action recognized that further consideration of additional standards pertaining to these unprotected uses was necessary. Accordingly, the Board has stated that it will conduct public hearings during 1969 and will consider before June 30, 1970, the matter of supplementing the salinity standards now established.

In reliance upon your State Board's commitment and, of course, reserving the position of the United States as a participant in such hearings as the holder of water rights for the Central Valley Project, I have approved the Delta salinity standards as submitted as far as they go. In addition, the Bureau of Reclamation has analyzed prospective operating conditions for the Central Valley Project and related water projects that affect Delta supplies, and it has concluded that the Central Valley Project and related projects can be operated during the interim period indicated by the Interior task force (until September 30, 1972) to conform to the recommendations of the task force, including paragraphs B2 and B5, which provide the following:

> B2: Above Three Mile Slough in Sacramento River and between Jersey Point and Venice Island in San Joaquin and False Rivers, except in below normal dry and critical years, there shall be maintained a daily mean total dissolved solids concentration of:
>
> a. 350 milligrams per liter or less from April 1 until the water temperature at these locations reaches 60°F,
>
> b. 180 milligrams per liter or less thereafter for five weeks. This provision shall continue in effect until the initial operation of the Peripheral Canal at which time modification to enhance striped bass spawning in interior Delta channels shall be considered.
>
> B5: Within the normal operating capability of local, state and Federal water projects there shall be maintained at Antioch in the San Joaquin River until September 30, 1972 a mean total dissolved solids concentration of 450 milligrams per liter when measured on the basis of the average of the daily mean values for any 10 consecutive days throughout a period of at least 150 days each water year, except that the period is reduced to 120 days during dry years and 100 days during critical years; provided; that the criteria contained in this paragraph shall not apply when contractual arrangements regarding substitute supplies have been completed between the water users in the Delta and the State and the Federal governments.

The Bureau of Reclamation has proposed that the Central Valley Project be operated on this basis during the interim period (until September 30, 1972) to be monitored jointly by the Bureau and the Federal Water Pollution Control Administration, and I have concurred, so that existing water quality conditions in the Delta can be maintained. Upon the submission pursuant to the Federal Water Pollution Control Act by your State of additional standards for approval pursuant to that Act concerning the matters included in the task force's recommendations, the Department will, of course, review the situation as it may then appear. The Department must also reserve its freedom of action with respect to the operation of the Central Valley Project and under the Federal Water Pollution Control Act in the event additional standards are not forthcoming from your State on or before June 30, 1970.

I have approved the Water Quality Control Policy for the San Francisco Bay area on the basis that the soon-to-be-completed Bay-Delta study will lead to the development of a detailed implementation plan for better waste treatment and control than that now being accomplished and required. We recognize the significance of this study, and we understand that it will develop recommendations for a totally new and far-reaching water quality management program. We will expect that these recommendations will be incorporated in the San Francisco Bay area standards and submitted to the Department of the Interior as soon as this can appropriately be accomplished.

I am concerned about your State's waste treatment policies which allow the discharge of untreated and primary-treated wastes, digested sludge, oil field brines and heated wastes into certain confined waters, such as harbors and bays, and into certain nearshore waters. In my approval of the California standards, I have assumed that the non-degradation policy your State Board adopted will cause a review and modification of these policies and will lead to a revision of waste discharge requirements where appropriate. We therefore will expect that amendments to the implementation plans of your State's standards will be made and submitted to the Department of the Interior before January 1, 1970.

I would like to comment further on several other aspects of California's standards which I feel also need additional attention. For example, numerical bacteriological objectives have not been established for the Smith, Klamath and Colorado Rivers, the interstate streams of the Lahontan Region and Lake Topaz. These are prime recreation waters which we believe should be protected by specific bacteriological parameters. I understand that your State Department of Public Health is currently surveying these waters to develop appropriate numerical objectives for consideration by your State and Regional Boards. I urge early completion of this work and formal adoption of amendments for our consideration as Federal standards.

I also note that bacteriological objectives have not been established to protect sport fishing, boating and other secondary contact recreational uses in certain tidal waters such as the San Gabriel River tidal prism above Marine Drive, Los Cerritos Channel and Calleguas Creek tidal prisms and Hueneme and Channel Islands Harbors. Your State Department of Public Health has established adequate bacteriological objectives and an excellent program of monitoring for public beaches and most other prime recreation waters. I recommend that a similar approach be taken in secondary contact recreational waters, and that appropriate bacteriological objectives be adopted for this purpose as early as possible.

Standards for the Lost River and specific standards for the minor interstate streams of the Lahontan Region were not included among the Water Quality Control Policies submitted by California. I understand however, that a draft of a policy for the Lost River has been completed.

I anticipate that Oregon will formulate standards for its portion of this river before June 30, 1969. Following this date, we would like to take action on the standards submitted by both States. Regarding the minor interstate streams of the Lahontan Region, I ask that specific standards be developed as soon as sufficient water quality data and other necessary information become available.

Finally, I would like to direct attention to two items for future consideration regarding the New and Alamo Rivers. When the discharge of untreated wastes into the New River by Mexicali, Mexico, has been corrected, an upgrading of the Water Quality Control Policies for these two rivers would be appropriate. I believe that the present requirement of a minimum of primary waste treatment should be raised to secondary treatment, and that bacteriological criteria to protect secondary contact recreational and other incidental contact uses of these waters should be established. These features would facilitate full usage of the New and Alamo Rivers as well as enhance the water quality and uses of the Salton Sea. I would appreciate careful consideration of these recommendations by your State and Regional Boards.

Successful implementation of the standards is the key to accomplishing our mutual goals of protecting and enhancing the quality and productivity of interstate waters. Adherence to the waste treatment requirements and time schedules specified in your State's implementation plans is very important if we are to achieve these goals. The annual State program plan, which your State Water Resources Control Board prepares and submits to the Federal Water Pollution Control Administration in connection with our grant program can provide a basis for updating information on the status of implementing the standards.

Lastly, it is evident that our waste treatment and water pollution control technology will advance and knowledge of water quality data will make more information available to assure more accurate assignment of water quality objectives. As this new knowledge becomes available, we will further expect to cooperate with the State of California in making necessary amendments to the standards that have been theretofore approved. It will be our pleasure to continue to work together to protect, upgrade and enhance the quality of the waters of your State.

Sincerely yours,

(sgd) Stewart L. Udall

Secretary of the Interior

Honorable Ronald Reagan
Governor of California
Sacramento, California 95814